IMPROVING THE VOLTAGE RUNTIME WITH THE COMBINATION OF MANGANESE BATTERY AND ULTRACAPACITOR

WAN ZULFADZHLI BIN WAN ZAKI

ELECTRICAL & ELECTRONICS ENGINEERING
UNIVERSITI TEKNOLOGI PETRONAS
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by

WAN ZULFADZHLI BIN WAN ZAKI

Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

Universiti Teknologi Petronas
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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Approved:

____
(Puan Azizan binti Zainal Abidin)
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

JUNE 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Wan Zulfadzhli bin Wan Zaki

ABSTRACT

The usage of electrical and electronic devices nowadays is not an indicator of luxury anymore but a necessity for each person in this world. Consumers in this new era not only search for the quality products of electrical and electronic devices, but more than that which is to find the products that can sustain for a longer time period besides can provide enough electrical energy on a certain time. The advance and modern technology these days give a new perspective to engineers and designers in order to manage the power and energy used in electrical and electronic product. In line with that, the objective of this project is to utilizing the ultracapacitor by combine it with the battery in order to improve the runtime of electrical devices products over the battery-only system. That combination also called hybrid power system. Besides that, the unique properties that have on ultracapacitor make it the most suitable component to be pulsed power provider which can provide high electrical energy on a certain time especially at the initial operation of each electrical and electronic devices product, thus it can improve the battery capability for power peaks as well as to extend battery lifetime. The delivery and scope of this project is the working prototype that involves battery and ultracapacitor besides other devices and hardwares such as DC load and switch. The design of the circuit arrangement will be simulated via circuit simulation software, National Instruments™ (NI) Multisim Analog Devices Edition and DataStudio to check the reliability of the designed circuit. A few tests then will be conducted on the prototype by using breadboard for data gathering purpose by using various values of capacitance of ultracapacitor as well as various quantity of manganese battery as the charging source and power supply in term of voltage to the ultracapacitor and DC load before construct the final circuit on veroboard. The main references for this project are journals or magazines, text books, conference proceedings, websites as well as open access contents.

ACKNOWLEDGEMENTS

First and foremost, praise Allah the Almighty, who has helped and gave me courage and strength in completing the Final Year Project (FYP). Without His permission, this FYP will not be a success.

I would like to take this opportunity to express my deepest gratitude to all parties involved in conducting this project ranging from UTP lecturers, technician and graduate assistants to external organizations who have put a large effort in making this project a success.

I am profoundly grateful to my supervisor, Puan Azizan Zainal Abidin as well as to my co-supervisor, Dr. Mumtaj Begam Kasim Rawthar who has guided and given me the opportunity to handle the project. The compliment should also go to all Electrical and Electronics Engineering lecturers and technician for bundles of information and assistance in completing this project especially to Ms. Siti Hawa and Ms. Noorsyawaliza.

I would also like to give special thanks to my parents and classmates for giving continuous support and motivation throughout compeleting this project. Last but not least, many thanks to others whose name was not mentioned in this page but has in one way or another contributed to the accomplishment of this project. Thank you very much.

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LIST OF ABBREVIATIONS

EDLC	Electric Double Layer Capacitors
UPS	Uninterruptible Power Supply
EHV	Hybrid Electric Vehicles
kJ	KiloJoule
NI	National Instruments
RF	Radio Frequency
AC	Alternate Current
DC	Direct Current
ESR	Equivalent Series Resistance
PTFE	Polytetrafluoroethylene (Teflon)
EE	Electrical and Electronics
TM	Trademark

CHAPTER 1
INTRODUCTION

1.1 Background Of Study

Ultracapacitor, also known as supercapacitor or EDLC (electric double layer capacitors) is one of the electrochemical energy storage devices in the power industry besides fuel cell and rechargeable secondary battery such as lead acid battery, Ni-MH battery and lithium ion battery. The advantages of the ultracapacitor compared to the conventional batteries make it applicable in numerous applications including lighting systems, uninterruptible power supply (UPSs), hybrid electric vehicles (EHV), buses and trains, consumer electronic devices, power tools, windmills, industrial equipment and telecommunication systems [1].

Apart from being on energy storage device, ultracapacitor also functions as the provider of pulsed power. Pulsed power is the term used to describe accumulating energy over a relatively long period time and releasing it very quickly thus increasing the instantaneous power. Some applications that need this pulsed power technology include particle accelerators, radar, fusion research, high power pulsed lasers, electromagnetic pulses and ultrastrong magnetic fields [2].

This project will use the advantages of the ultracapacitor and focus on the application of energy storage and the pulsed power provider device as it absorbs and protect against any sags and surges in the voltage that could damage or limit the power of battery. The delivery of this project is the working prototype that involves battery and ultracapacitor which will show the different waveforms between various value of capacitance of ultracapacitor and to compare the results of battery-only system and battery-ultracapacitor system.

1.2 Problem Statement

Most electrical devices such as digital cameras and computers use alkaline or rechargeable batteries as its storage device. The usage of batteries requires frequent recharging besides the replacement of the batteries in the case of alkaline batteries [3]. Thus, the effect of recharging and replacing of the batteries will increase the cost hence burden the end users. In order to overcome such problems, the advantages of the ultracapacitor can be implemented.

Besides that, the problem in providing the pulsed power to increase the instantaneous power also contributes to why ultracapacitor is a better choice as an alternative to provide that pulsed power within faster rate because of its energy storing ability.

1.3 Objectives and Scope Of Study

The major goal for this project is to enhance the life of a battery by using a combination of ultracapacitor with the battery itself. The combination of battery and ultracapacitor is known as hybrid power system. Furthermore, this combination will further extend the battery life span, hence reducing cost.

This project will also show that the combination of ultacapacitor and battery can provide pulsed-power and accommodate a peak power demand to increase instantaneous power, thus the batteries will not have to be oversized because the pulsed-power to accommodate a peak power demand now can be obtained from the combination of battery-ultracapacitor system instead of battery-only system which need a lot of batteries.

The scope of this project is to design and build a complete circuitry system of a working prototype and can be simulated using PSpice, NI Multisim Analog Devices Edition and DataStudio

This project is expected to be completed within a time frame of twenty-five (25) weeks. The first half of the period is to explore and learn more about ultracapacitor regarding its theories, properties and elements beside some preliminaries testing of the prototype. The second half of the time frame is to complete and to run tests of the prototype. The design and the construction of the prototype will begin with circuit simulation using circuit simulation software before using bread board as testing devices. The final development of the circuit construction will be done after all the hardware used is soldered on the veroboard.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction to Ultracapacitor

In general, capacitors can be divided into two types which are fixed capacitors (refer to Table 1) and variable capacitors. The difference between fixed capacitor and variable capacitor is the capacitance of fixed capacitor cannot be adjusted while the capacitance of variable capacitor may be intentionally and repeatedly changed mechanically or electrically. Ultracapacitor (refer to Figure 1) is one from 24 other fixed capacitors because the capacitance of ultracapacitor cannot be adjusted mechanically nor electrically [7]. Even though ultracapacitor have been known since 40 years ago, it has gained popularity recently, especially amongst engineers. The reason is its ability to store large amounts of energy with the advantage of being capable of delivering such energy when needed (pulsed power) [8]. This is because of its properties of extremely large capacitance to volume ratio besides small in size. Some other unique properties of an ultracapacitor are [6]:

- high capacitance density
- low cost per farad
- reliablility
- high and long cycle time
- free-operation maintenance
- environmentally safe (ultracapacitor do not have environmental concerns as some battery chemistries have)
- wide ranging of operating temperature
- high power density and good energy density
- high charging and discharging rate

Table 1 below shows the different types of fixed capacitors:

Table 1: Properties of Different Types of Fixed Capacitors [7]

No.	Types of Capacitors	Dielectric Used	Features	Applications
1.	Vacuum capacitors	Highly evacuated glass or ceramic chamber with concentric cylindrical electrodes	Extremely low loss	High voltage high power RF applications such as transmission and induction heating
2.	Direct current oil-filled capacitors	Paper or paper-polyester film combination	Large in size	DC applications such as filtering, bypassing, coupling, arc suppression and voltage doubling
3.	Electric double-layer capacitors (EDLC)	Thin electrolyte layer and activated carbon	Extremely large capacitance to volume ratio, small in size, low ESR	Temporarily provide power to equipment during battery replacement
4.	Lithium ion capacitors	Lithium ion	High power density	Used in wind power generations system
5.	Aluminum electrolytic capacitors	Aluminum oxide	Very large capacitance to volume ratio	As smoothing and reservoir capacitors in power supplies
6.	Class-I temperature compensating type ceramic capacitors	Mixture of complex titanate compunds	Low cost, small size	Used in moderately high-frequency work

No.	Type of Capacitor	Dielectric Used	Features	Applications
7.	Class-II high dielectric strength type ceramic capacitors	Barium titanate based dielectrics	Small in size	Used in application to achieve the capacitance required at any given temperature, voltage or frequency is critical
8.	Metalized mica / silver mica capacitors	Mica	Much reduced moisture infiltration	Use to tuned elements of circuits like oscillators
9.	Metalized plastic film capacitors	Polyester or polycarbonate	Reliable, small in size	Making capacitors 'self healing'
10.	PTFE fluorocarbon (Teflon) film capacitors	Polytetra-fluoroethylene	Lower loss solid dielectric	Used in stringent, mission-critical applications
11.	Polypropylene plastic film capacitors	Polypropylene	Extremely low dissipation factor, low moisture absorption	Used in high frequency applications
12.	Polystrene capacitors	Polystyrene	Excellent stability, low moisture pick-up	Used in low power RF and precision analog applications
13.	PET film capacitors	Polyester film	Small in size	Used in DC electronic applications
14.	Paper capacitors	Paper or oil-impregnated paper	Using wax, oil or epoxy as an impregnant	Used in certain high voltage applications

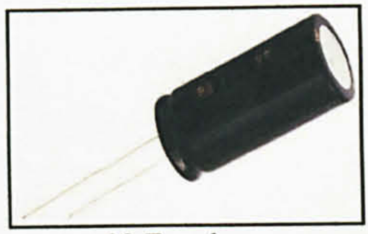
No.	Type of Capacitor	Dielectric Used	Features	Applications
15.	Energy storage capacitors	Kraft capacitor paper impregnated with electrical grade castor oil	High current discharge	Used in pulsed power, electromagnetic forming, pulsed lasers
16.	Alternating current oil-filled capacitors	Oil-impregnated paper	High peak voltage at power line frequencies	Used in AC motor starting and running, phase splitting
17.	Tantalum electrolytic capacitors	Tantalum oxide	Large capacitance to volume ratio, small in size	Used in miniaturized equipment and computers
18.	Glass capacitors	Glass	Ultra-reliable, ultra-stable, resistant to nuclear radiation	Used in radio frequency circuit design
19.	Stacked plate mica capacitors	Mica	Does not change physically or chemically with age	Used in extremely high-G applications
20.	Polyamide plastic film capacitors	Polyamide	High insulation resistance, good stability	Used in bypassing and coupling applications
21.	Polysulphone plastic film capacitors	Polysulfone	Can withstand full voltage at comparatively higher temperatures	Used in motor run, microwave oven, magnetic ballast
22.	Polycarbonate plastic film capacitors	Polycarbonate	Duperior insulation resistance	Used in full operating voltage across entire temperature range

23.	Kapton capacitors	Kapton polyimide film	High operating temperature	Used in planar speakers and transducers
24.	Metalized paper capacitors	Paper	Small in size	Used for interference suppression in audio applications

The lowest capacitance of ultracapacitor that available in market up until today is 0.047 Farad while the biggest capacitance of ultracapacitor is 70 Farad. Figure 1 below shows three different capacitance of ultracapacitor which will be used in this project:

0.33 Farad

1.0 and 1.5 Farad



22 Farad

Figure 1: Wide nominal capacitance range of ultracapacitor [9]

2.2 Properties and Components of Ultracapacitor

An ultracapacitor consists of two metal plates which are separated by an insulator just like an ordinary capacitor (refer to Figure 2). The difference between ordinary capacitors and ultracapacitor is located at the separator between the two plates which is the insulator or also known as separator [8].

The separator for ultracapacitor is porous and is soaked in an electrolyte. Positive and negative ions move in opposite directions and cling to their respective electrodes because ions that form in the electrolyte can move freely through the separator. The most important features on the ultracapacitor are is inner surface at each electrode. This is because that inner surface is not a smooth surface but is rather padded with activated (porous) carbon. This results in a surface area that is about 100,000 times as large as the surface area of an ordinary capacitor [8].

Figure 2 below shows the cross-sectional view of ultracapacitor and label of each component:

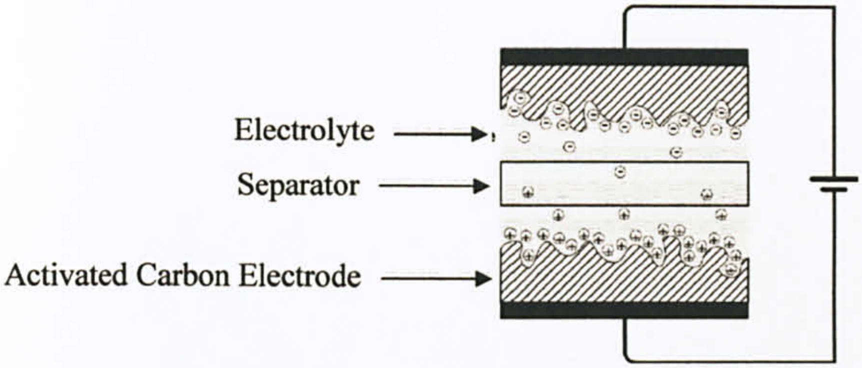
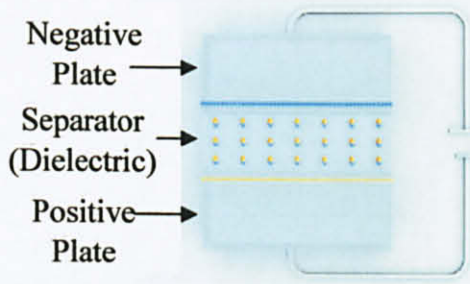
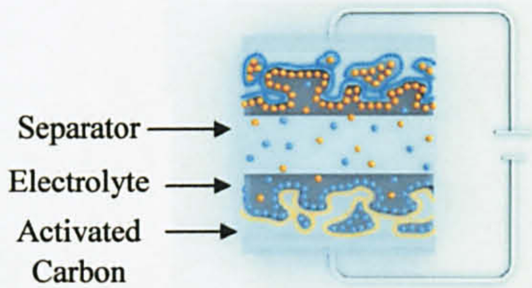


Figure 2: Cross-sectional view of ultracapacitor [8]

Table 2 below shows the differences between typical capacitor with ultracapacitor in term of cross-sectional view, its plates as well as the ions movement within that typical capacitor and ultracapacitor.

Table 2: Comparison between typical capacitor with ultracapacitor

Type of capacitor	Typical Capacitor	Ultracapacitor
Cross-sectional view		
Plates	Plain old plates	Plated packed with ions
Ions movement	Electrons are removed from one plate and deposited on the other. Polarized molecules in the dielectric concentrate the electric field	An ultracapacitor can store more charge than a capacitor can because the activated carbon has a pocked interior, much like a sponge. This means that ions in the electrolyte can cling to more surface area

The capacitance, C, of a parallel-plate capacitor equation is given by [8]:

$$C = \frac{\mathcal{E}A}{d}$$

Where

$\mathcal{E}$ = $\mathcal{E}o\mathcal{E}r$, the product of the dielectric constant of the insulator, $\mathcal{E}o$ and the permittivity of free space, $\mathcal{E}r$,

A = the area of the electrode, and

d = the distance between the positive and the negative concentrations of charges.

Based on the capacitance of a parallel-plate capacitor equation, it is clearly shows that by maximizing the value of A and minimizing the value of d, a higher value of capacitance can be obtained. That is the reason why ultracapacitor can achieve extremely high values of capacitance. For record, the highest value of capacitance of ultracapacitor to this day and age is 5000-Farad where it is very useful in numerous applications such as hybrid drive trains, automotive subsystems, transportation as well as rail system power.

2.3 Storage Mechanism

Ultracapacitor is the electrochemical capacitor and is mainly divided into two categories based on the charge storage mechanisms [6]. The first charge storage mechanism stores the charge in chemical double layers that results in the interface between the electrodes and electrolyte and the second charge storage mechanism stores the energy through a redox reaction. The redox reaction is a reversible process between multiple oxidation states in the electrode material. This second mechanism which is the redox reaction is the mechanism being used for ultracapacitor.

The redox reaction in ultracapacitor is a very simple process which involves an electronic and proton intercalation or electrosorption process. This will make the movement of charges in the electrosorption process to occur rapidly and with little internal resistance.

The other energy storage unit such as battery applies an energy conversion process where it involves multiple complex Faradaic reactions. As a result, the heat will be generated inside the battery because of the slow chemical reactions when it either delivers or receives current. The equation that shows the heat generated inside the battery, Q is shown below [6]:

$$Q = I\,(\eta + IR) + I\,[(dE^o/dT)T]$$

Where

η = cell polarization (overpotential),

R = ohmic (electronic and electrolytic) resistance,

E^o = thermodynamically defined equilibrium cell voltage (cell potential),

I = current flow,

T = time, and

$\frac{dE}{dT}$ = discharge rates.

The second term on the right hand side of that equation which is $I[(dE^o/dT)T]$ represents the reversible heat (entropy effect). That reversible heat may contribute about 10-20% of the electrical energy produced in the discharge.

While the first term on the right hand side which is $I(\eta + IR)$ represents the irreversible heat, which is the results from the battery voltage loss under the current flow, I. As a result, at high discharge rates, for instance with pulse current applications, significant heat can be generated within the battery. That heat will cause deleterious effects such as shortened life and increased internal resistance as well as reduces the efficiency of electrical generation.

Based on the storage mechanism inside the ultracapacitor (electrochemical capacitor), it clearly shows that only minimal heat is generated from the I^2R effects. Consequently, for pulsed power applications, the combination of the ultracapacitor with battery (hybrid electrochemical) system should deliver higher power much more efficiently.

CHAPTER 3
METHODOLOGY

3.1 Procedure Identification

3.1.1 Part I

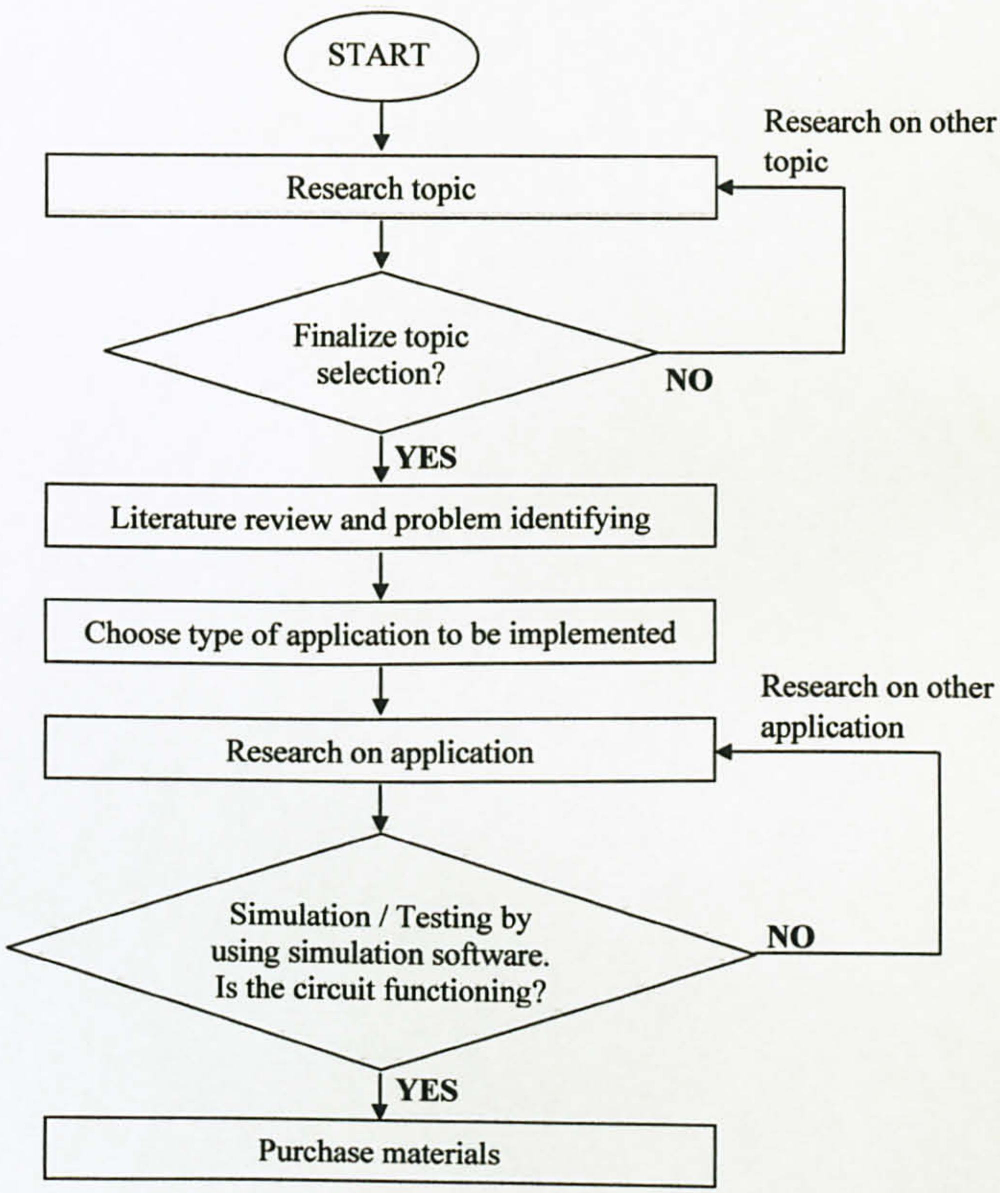


Figure 3: Project flow for part I

3.1.2 Part II

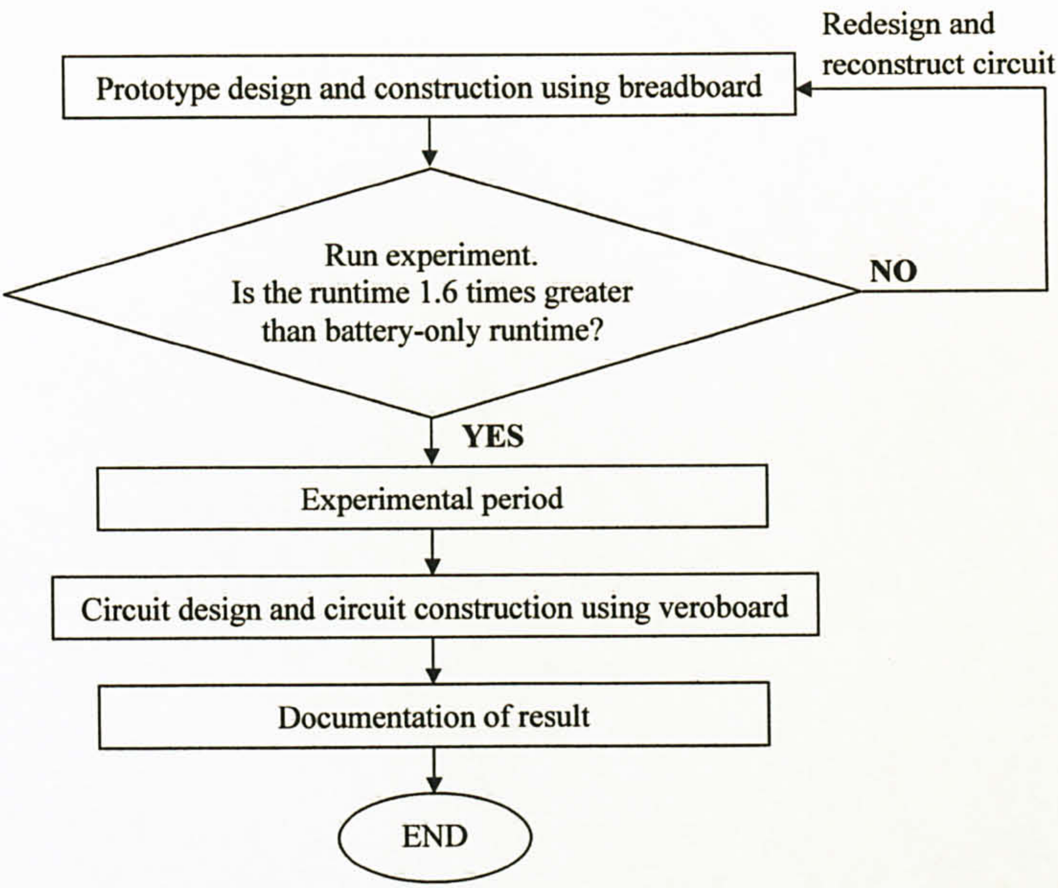


Figure 4: Project flow for part II

3.2 Tools and Equipments Required

3.2.1 Hardware

The tools that will be used in designing the complete circuitry system of a working prototype are some hardware such as ultracapacitor, battery, ScienceWorkshop® 750 Interface, voltage sensor, multimeter, DC load and AC-DC converter.

The ultracapacitor or supercapacitor is a direct current (DC) device and will be used as an energy storage unit for power during use [3]. The ultracapacitor charging voltage depends on the battery chosen. The first step in incorporating ultracapacitor into a load is determining the appropriate input power available to the ultracapacitor and the required output power from the ultracapacitor where it can be done by referring to the technical information and product specifications of the ultracapacitor chosen.

The battery with voltage rated at 1.5V that will be used for this project is manganese batteries (refer to Figure 5) as the primary choice due to the relative cost compared to other chemistries. Furthermore, manganese battery is available from most shops. This battery will act as the charging source for the chosen load. Figure 5 below shows the manganese battery which will be used in this project:

Figure 5: Manganese battery [11]

ScienceWorkshop 750 Interface (refer to Figure 6) is the hardware that will enable experiments to run and display results using the computer. For this project, varying voltage across the load can be measured and the results will be displayed on the computer screen in the form of graph and table of values. This ScienceWorkshop 750 Interface is available upon request at Physic's Lab. Figure 6 below shows how ScieceWorkshop® 750 Interface looks like:

Figure 6: ScienceWorkshop® 750 Interface [12]

The voltage sensor (refer to Figure 7) is the connector between the ScienceWorkshop® 750 Interface and an electronic circuit. This voltage sensor includes both standard banana plugs and alligator clips which are capable to measure the voltage across the load up to ±10 V AC/DC. This voltage sensor is also available upon request at Physic's Lab. Figure 7 below shows the voltage sensor which will be connected to the ScienceWorkshop® 750 Interface at one terminal (input) and to the experimented circuit (output) at another terminal:

Figure 7: Voltage sensor [13]

The multimeter (refer to Figure 8) or also known as multitester is an electronic measuring instrument [14]. This multimeter is the digital type of multimeter that will be used to measure the voltage, current and resistance in the tested electronic circuit as it combines several measurement functions in one unit. Besides that, this multimeter will also be used to verify the voltage readings across the load that are measured by both ScienceWorkshop® 750 Interface and voltage sensors. This multimeter is available in EE labs. Figure 8 below shows the digital multimeter which will be use along this project:

Figure 8: Digital multimeter [14]

The AC-DC converter (refer to Figure 9) will act as the power supply because of its output voltage adjustable abilities. The input voltage for this AC-DC converter is AC 240V (50Hz) and the DC output voltage are adjustable to 3V, 4.5V, 6V, 7.5V, 9V and 12V. This AC-DC converter will be used to test the electronic circuit to check whether that circuit is working or not before the battery being plugged in into that circuit in order to reduce the battery cost. This AC-DC converter can be obtained from the local EE components distributor nearby. Figure 9 below shows the AC-DC converter which will act as the power supply in term of voltage into the experimented circuit:

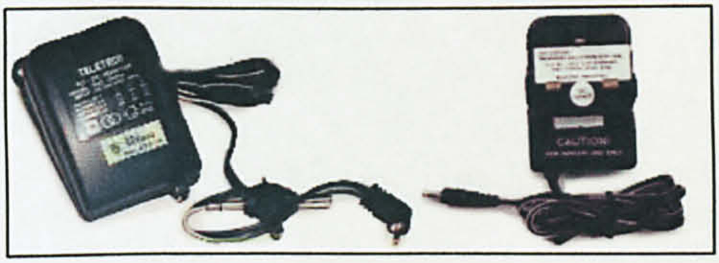


Figure 9: AC-DC converter [16]

The DC load that will be used in this project is the 6.3V, 3W light bulb (refer Figure to 10). This light bulb will be attached with its holder that connected with the wires. The electronic measuring instruments such as digital multimeter and the voltage sensor of the ScienceWorkshop® 750 Interface will be put across this light bulb to measure the voltage across it. Furthermore, this light bulb will also act as an indicator of the tested electronic circuit based on its brightness. This light bulb can be obtained from the local EE components distributor nearby. Figure 10 below shows the light bulb which will act as the device or application in this project:

Figure 10: Light bulb [17]

This experiment involves several tests that includes arrangement of series and parallel connection between the battery and ultracapacitor, stand- alone battery as power source as well as using the different capacitance values of ultracapacitor in order to get the best arrangement.

3.2.2 Software

The software required to implement this project involved:

- PSpice and NI Multisim™ Analog Devices Edition

  Due to the incompatibility of the PSpice software with the latest version of windows operating software (Windows Vista), NI Multisim™ Analog Devices Edition (refer to Figure 11) is the most suitable alternative simulation software for this project. It is the schematic capture and simulation application of National Instruments™ Circuit Design Suite that will be used to predict the behavior of a real circuit. Figure11 below shows the Graphic User Interface (GUI) of NI Multisim™ Analog Devices Edition software:

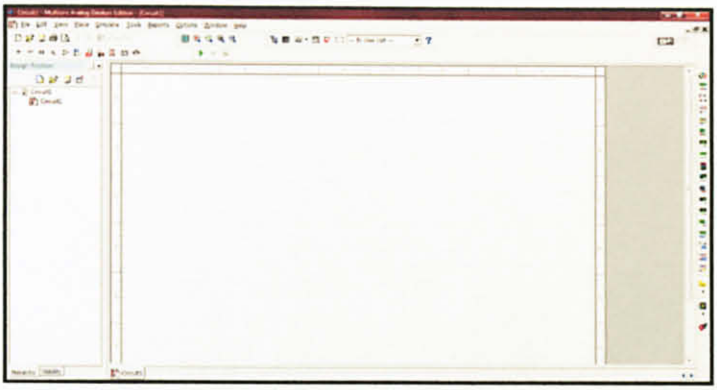


Figure 11: User interface of NI Multisim™ Analog Devices Edition

- DataStudio

  This is a data acquisition, display and analysis program (refer to Figure 12) which works with ScienceWorkshop 750 Interface and voltage sensor to collect, record and analyze data from the tested electronic circuit. Figure 12 below shows the home graphic user interface of DataStudio. Figure 12 below shows the Graphic User Interface (GUI) of DataStudio software:

Figure 12: User interface of DataStudio

CHAPTER 4
RESULTS AND DISCUSSIONS

4.1 Circuit Arrangement

In this project, there will be a few types of circuit arrangements that will be tested. These circuit arrangements will also be used as the comparison indicator between stand-alone battery circuit arrangement, series connection between ultracapacitor and battery circuit arrangement and parallel connection between ultracapacitor and battery arrangement. The capacitance value of the ultracapcitor will be varied and not restricted to only one capacitance value. The circuit arrangements are as follows:

a) Stand-alone battery

This circuit arrangement (refer to Figure 13) will be equipped with one or two batteries which is rated at 1.5V each, switch, light bulb as the DC load and voltmeter as an electronic measuring instrument to measure the voltage across the light bulb. Figure 13 below shows the circuit arrangement for stand-alone battery system:

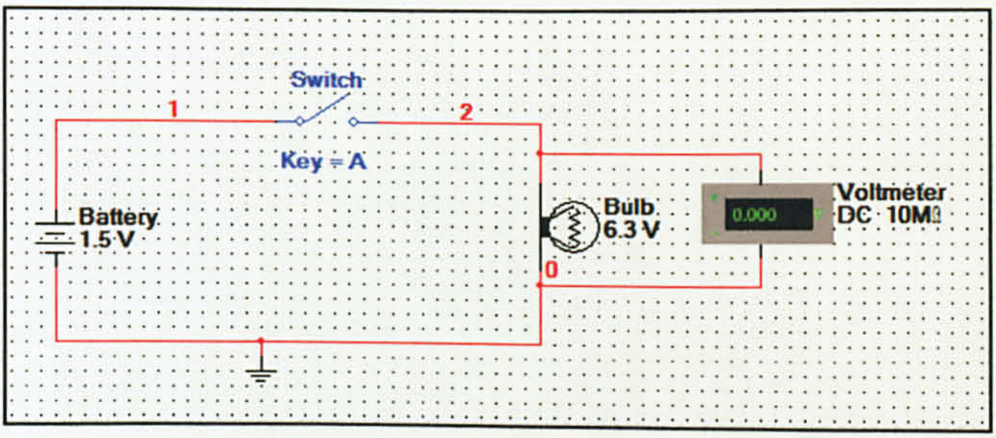


Figure 13: The circuit arrangement for stand-alone battery

b) Series connection between ultracapacitor and battery

This circuit arrangement (refer to Figure 14) will be equipped with one one or two batteries which is rated at 1.5V each, ultracapacitor (with capacitance of 330 miliFarad, 1000 miliFarad, 1500 miliFarad and 22000 miliFarad) as energy storage device, switch, light bulb as the DC load and voltmeter as an electronic measuring instrument to measure the voltage across the light bulb. Figure 14 below shows the circuit arrangement for series connection of battery-ultracapacitor system:

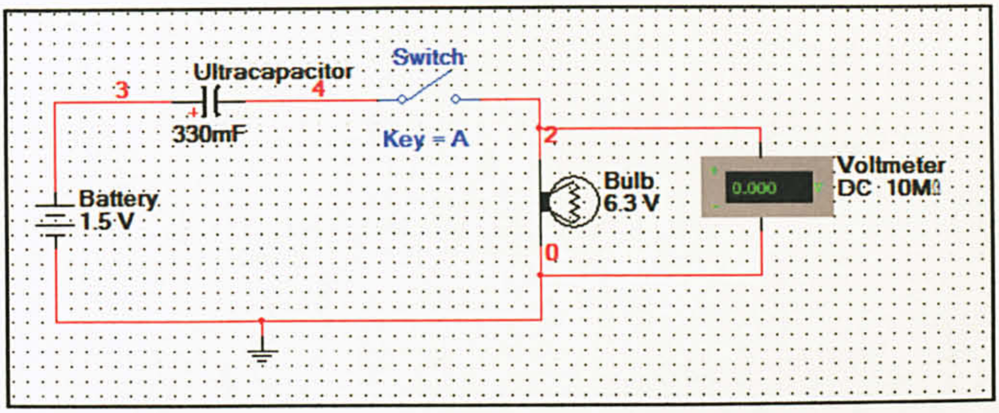


Figure 14: The circuit arrangement for series connection

c) Parallel connection between ultracapacitor and battery

This circuit arrangement (refer to Figure 15) will be equipped with one or two batteries which is rated at 1.5V each, ultracapacitor (with capacitance of 330 miliFarad, 1000 miliFarad, 1500 miliFarad and 22000 miliFarad) as energy storage device, switch, light bulb as the DC load and voltmeter as an electronic measuring instrument to measure the voltage across the light bulb. Figure 15 below shows the circuit arrangement for parallel connection of battery-ultracapacitor system:

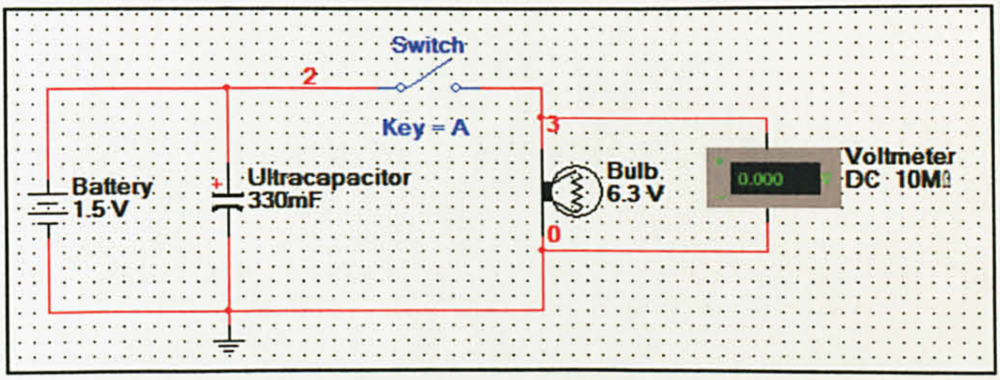


Figure 15: The circuit arrangement for parallel connection

4.2 Results

The results for this project are based on the experimented circuit arrangements used as well as the capacitance value of each ultracapacitor connected into the circuit. There are 3 types of experimented circuit arrangements used which are:

- stand-alone battery circuit arrangement
- series connection between battery and ultracapacitor circuit arrangement
- parallel connection between battery and ultracapacitor circuit arrangement

The results obtained also depend on the quantity of the manganese battery used because it will determine the voltage supply into the load as well as into the ultracapacitor used. The manganese battery also acts as the charging source for the chosen load as well as to the ultracapacitor. For this project, there are two types of manganese battery's quantity will be used. The quantities of that manganese battery are:

- 1 manganese battery which will supply 1.5V of voltage
- 2 manganese batteries which will supply 3.0V of voltage

For the combination of battery and ultracapacitor, there are 4 different capacitance values of ultracapacitor used. Those capacitance values are:

- 330 miliFarad
- 1000 miliFarad
- 1500 miliFarad
- 22000 miliFarad

4.2.1 The Runtime of the Devices

For this section, the runtime of the devices or DC load chosen will be measured in term of voltage by using voltage sensor. The voltage will be measured across the DC load. The results obtained will be depending on the quantity of the manganese battery used which are 1 manganese battery and 2 manganese batteries. For each quantity of manganese battery, there will be 3 different types of circuit arrangement that will be tested. Those circuit arrangements are stand-alone battery circuit arrangement, series connection between battery and ultracapacitor circuit arrangement and parallel connection between battery and ultracapacitor circuit arrangement, and for parallel connection between battery and ultracapacitor circuit arrangement, there will be 4 values of capacitance of ultracapacitor used which are 330 miliFarad, 1000 miliFarad, 1500 miliFarad and 22000 miliFarad.

4.2.1.1 One Manganese Battery Circuit Arrangement

For this type of circuit arrangement, one battery with voltage rated at 1.5V is used as the voltage supply and charging source for the ultracapacitor as well as to the light bulb as DC load. The results for this type of circuit arrangement are as follows:

a) Stand-alone battery

For this type of circuit arrangement, the voltage waveform shows that the voltage across the load at hour 7.5 is 0.049V. Figure 16 below shows the voltage waveform for stand-alone battery system:

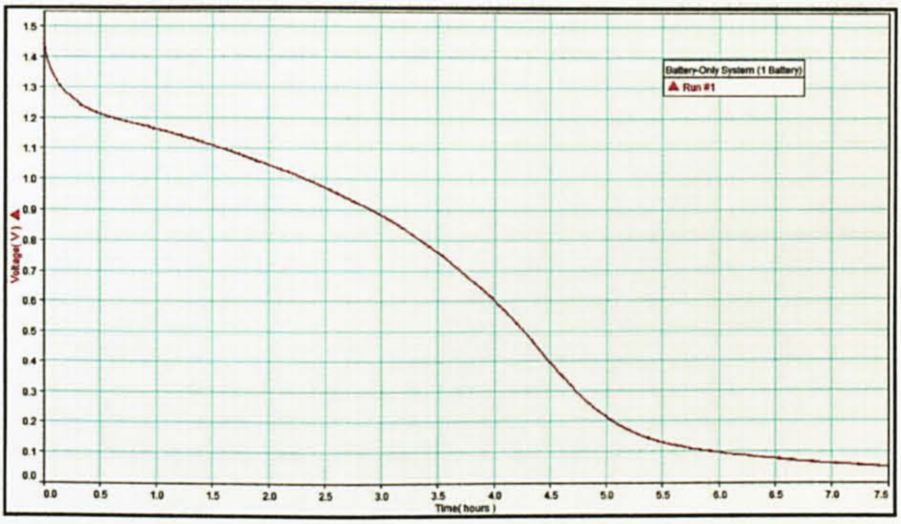


Figure 16: The voltage waveform across the light bulb for stand-alone battery circuit arrangement for 1 manganese battery (refer Appendix A.1 for full page view)

b) Series connection between battery and ultracapcitor

For this type of circuit arrangement, the voltmeter value shown that there is no voltage (0V of voltage) across the light bulb.

c) Parallel connection between battery and ultracapacitor

i. combination of 1.5V battery and 330 miliFarad ultracapacitor

- *For this type of circuit arrangement, the voltage waveform shows that the voltage across the load at hour 7.5 is 0.051V. Figure 17 below shows the voltage waveform for this circuit arrangement:*

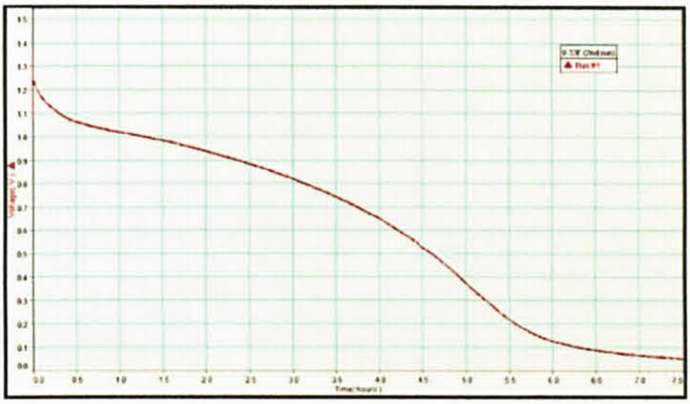


Figure 17: The voltage waveform across the light bulb for parallel connection between ultracapacitor (330 miliFarad) and battery for one manganese battery (refer Appendix A.2 for full page view)

ii. combination of 1.5V battery and 1000 miliFarad ultracapacitor

- *For this type of circuit arrangement, the voltage waveform (refer to Figure 18) shows that the voltage across the load at hour 7.5 is 0.046V. Figure 18 below shows the voltage waveform this circuit arrangement:*

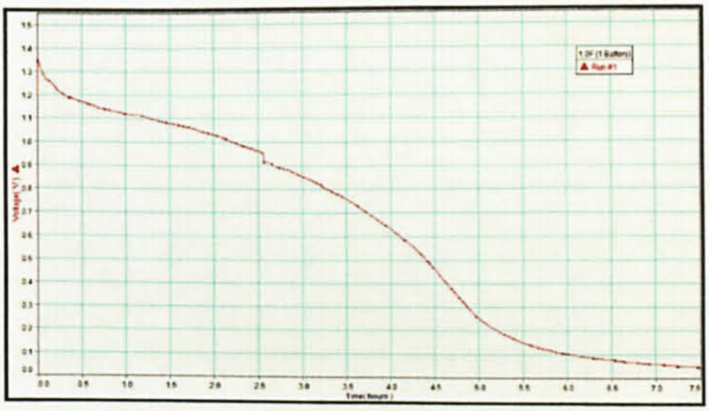


Figure 18: The voltage waveform across the light bulb for parallel connection between ultracapacitor (1000 miliFarad) and battery for one manganese battery (refer Appendix A.3 for full page view)

iii. combination of 1.5V battery and 1500 miliFarad ultracapacitor

- *For this type of circuit arrangement, the voltage waveform shows that the voltage across the load at hour 7.5 is 0.036V . Figure 19 below shows the voltage waveform for this circuit arrangement:*

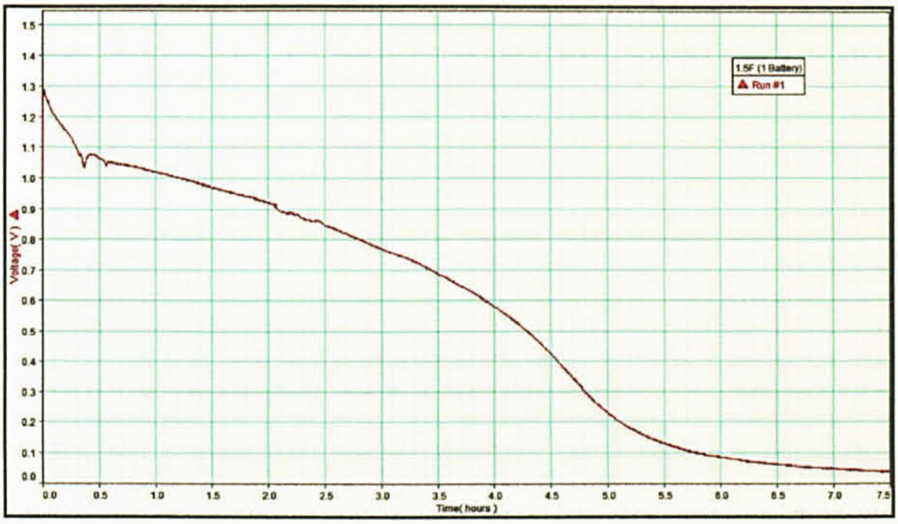


Figure 19: The voltage waveform across the light bulb for parallel connection between ultracapacitor (1500 miliFarad) and battery for one manganese battery (refer Appendix A.4 for full page view)

iv. combination of 1.5V battery and 22000 miliFarad ultracapacitor

- *For this type of circuit arrangement, the voltage waveform shows that the voltage across the load at hour 7.5 is 0.034V . Figure 20 below shows the voltage waveform for this circuit arrangement:*

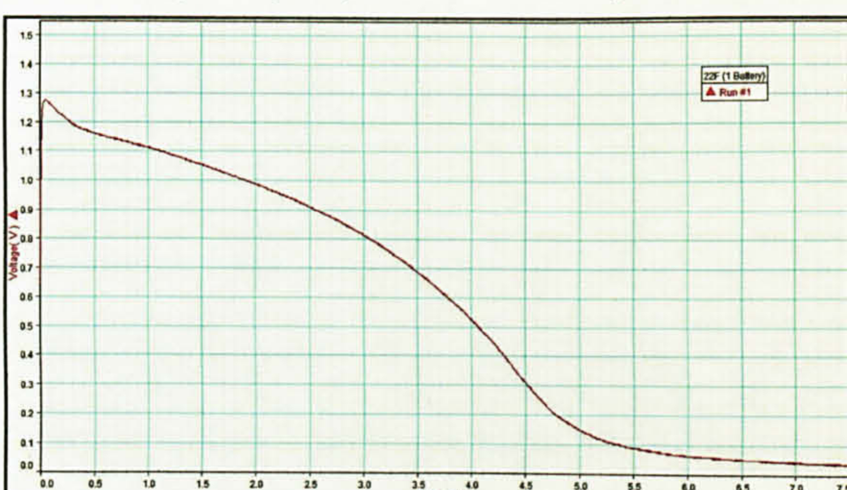


Figure 20: The voltage waveform across the light bulb for parallel connection between ultracapacitor (22000 miliFarad) and battery for one manganese battery (refer Appendix A.5 for full page view)

4.2.1.2 Two Manganese Batteries Circuit Arrangement

For this type of circuit arrangement, two manganese batteries with voltage rated at 3.0V (1.5V x 2) is used as the voltage supply and charging source for the ultracapacitor as well as to the light bulb as DC load. The results for this type of circuit arrangement are as follows:

a) Stand-alone battery

For this type of circuit arrangement, the voltage waveform shows that the voltage across the load at hour 15 is 0.007V. Figure 21 below shows the voltage waveform for stand-alone battery system:

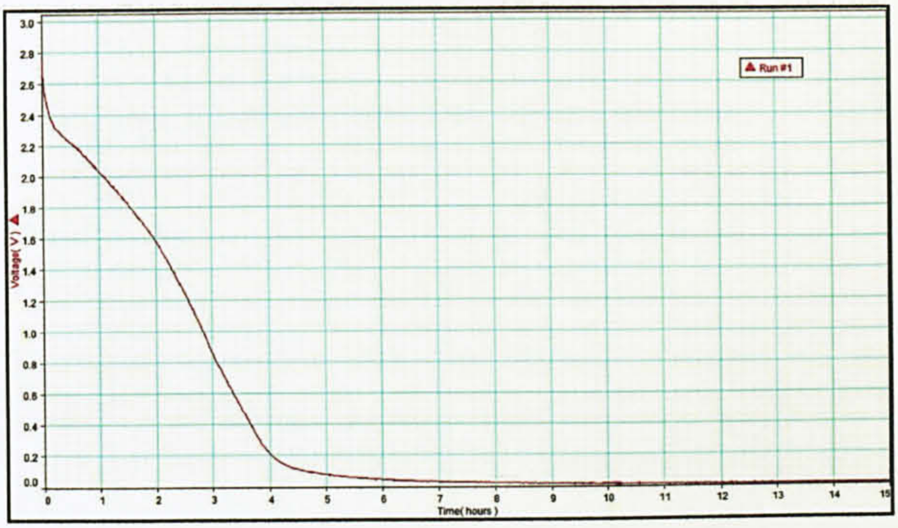


Figure 21: The voltage waveform across the light bulb for stand-alone battery circuit arrangement for two manganese batteries (refer Appendix B.1 for full page view)

b) Series connection between ultracapacitor and batteries

For this type of circuit arrangement, the voltmeter value shown that there is no voltage (0V of voltage) across the light bulb

c) Parallel connection between ultracapacitor and batteries

i. combination of 3.0V battery (1.5V x 2) and 330 miliFarad ultracapacitor

- *For this type of circuit arrangement, the voltage waveform shows that the voltage across the load at hour 15 is 0.007V. Figure 22 below shows the voltage waveform for this circuit arrangement:*

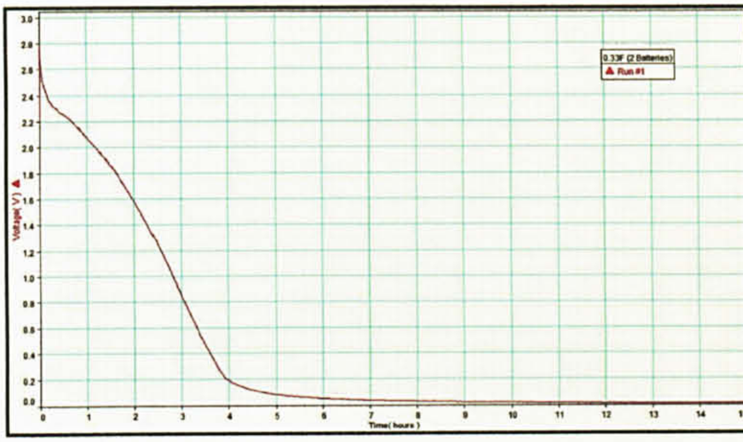


Figure 22: The voltage waveform across the light bulb for parallel connection between ultracapacitor (330 miliFarad) and battery for two manganese batteries (refer Appendix B.2 for full page view)

ii. combination of 3.0V battery (1.5V x 2) and 1000 miliFarad ultracapacitor

- *For this type of circuit arrangement, the voltage waveform shows that the voltage across the load at hour 15 is 0.016V. Figure 23 below shows the voltage waveform for this circuit arrangement:*

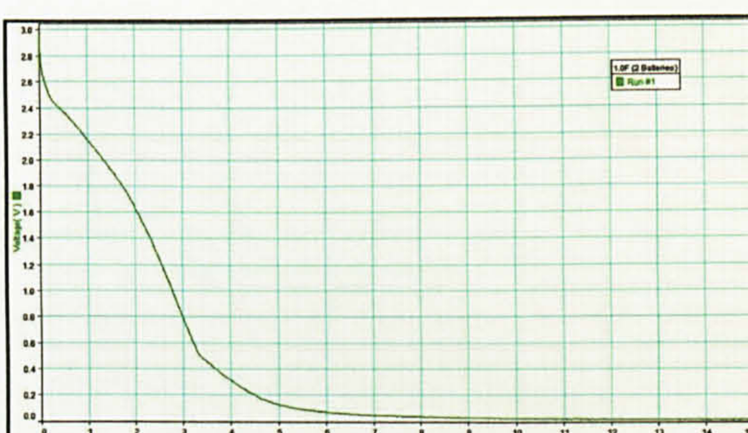


Figure 23: The voltage waveform across the light bulb for parallel connection between ultracapacitor (1000 miliFarad) and battery for two manganese batteries (refer Appendix B.3 for full page view)

iii. combination of 3.0V battery (1.5V x 2)and 1500 miliFarad ultracapacitor

- *For this type of circuit arrangement, the voltage waveform shows that the voltage across the load at hour 7.5 is 0.007V. Figure 24 below shows the voltage waveform for this circuit arrangement:*

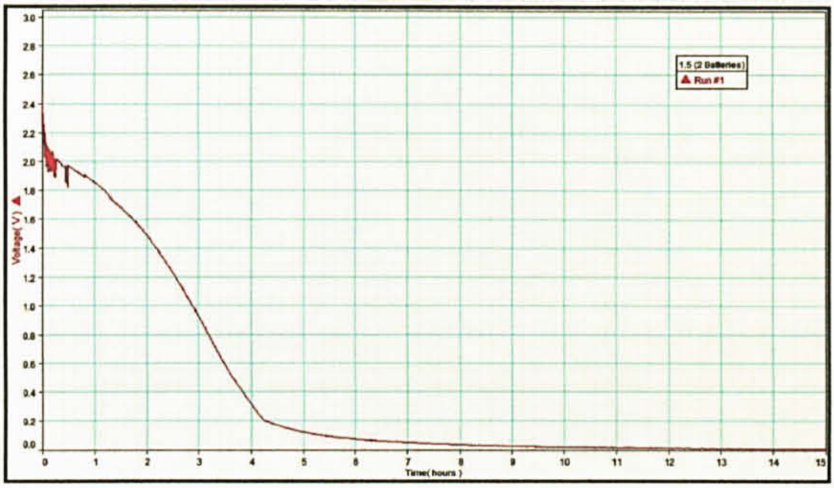


Figure 24: The voltage waveform across the light bulb for parallel connection between ultracapacitor (1500 miliFarad) and battery for two manganese batteries (refer Appendix B.4 for full page view)

iv. combination of 3.0V battery (1.5V x 2) and 22000 miliFarad ultracapacitor

- *For this type of circuit arrangement, the voltage shows that the voltage across the load at hour 15 is 0.025V. Figure 25 below shows the voltage waveform for this circuit arrangement:*

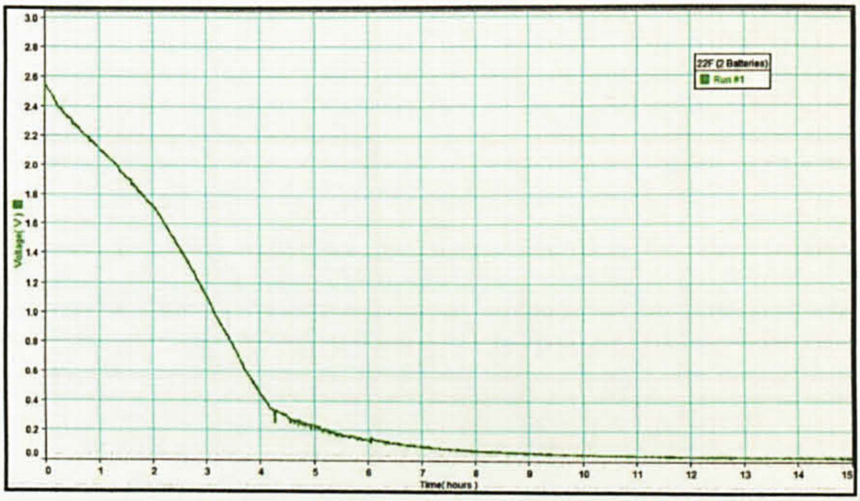


Figure 25: The voltage waveform across the light bulb for parallel connection between ultracapacitor (22000 miliFarad) and battery for two manganese batteries (refer Appendix B.5 for full page view)

4.2.2 Instantaneous power or Peak power

For this section, the instantaneous power or peak power of the devices or DC load chosen will be measured in term of voltage by using voltage sensor. The time range is between minute 0 to minute 1 of the waveform. The voltage will be measured across the DC load. The results obtained will be depending on the quantity of the manganese battery used which are 1 manganese battery and 2 manganese batteries. For each quantity of manganese battery, there will be 3 different types of circuit arrangement that will be tested. Those circuit arrangements are stand-alone battery circuit arrangement, series connection between battery and ultracapacitor circuit arrangement and parallel connection between battery and ultracapacitor circuit arrangement, and for parallel connection between battery and ultracapacitor circuit arrangement, there will be 4 value of capacitance ultracapacitor used which are 330 miliFarad, 1000 miliFarad, 1500 miliFarad and 22000 miliFarad.

4.2.2.1 One Manganese Battery Circuit Arrangement

For this type of circuit arrangement, one battery with voltage rated at 1.5V is used as the voltage supply and charging source for the ultracapacitor as well as to the light bulb as DC load. The results for this type of circuit arrangement are as follows:

a) Stand-alone battery

For this type of circuit arrangement, the voltage waveform shows that the average voltage across the load for the first one minute is 1. 238V. Figure 26 below shows the voltage waveform for stand-alone battery system:

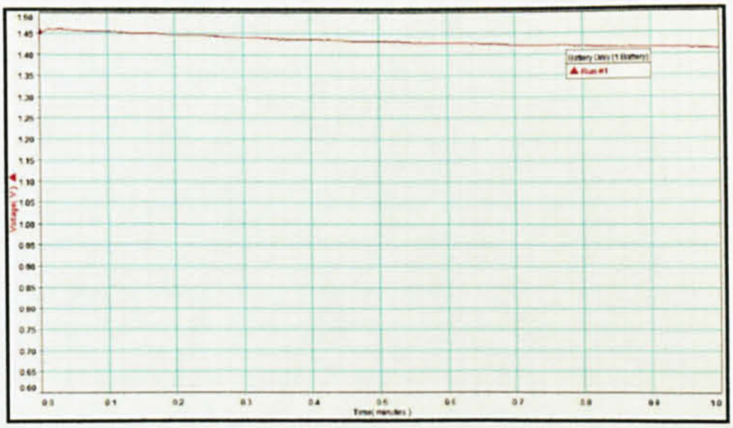


Figure 26: The voltage waveform across the light bulb for stand-alone battery circuit arrangement for the first one minute for one manganese battery (refer Appendix C.1 for full page view)

b) Series connection between battery and ultracapcitor

For this type of circuit arrangement, the voltmeter value shown that there is no voltage (0V of voltage) across the light bulb

c) Parallel connection between battery and ultracapacitor

i. combination of 1.5V battery and 330 miliFarad ultracapacitor

- *For this type of circuit arrangement, the voltage waveform) shows that the average voltage across the load for the first one minute is 1.252V. Figure 27 below shows the voltage waveform for this circuit arrangement:*

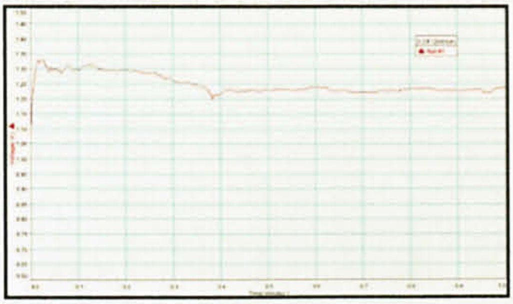


Figure 27: The voltage waveform across the light bulb for parallel connection between ultracapacitor (330 miliFarad) and battery for the first one minute for one manganese battery (refer Appendix C.2 for full page view)

ii. combination of 1.5V battery and 1000 miliFarad ultracapacitor

- *For this type of circuit arrangement, the voltage waveform shows that the average voltage across the load for the first one minute is 1.349V. Figure 28 below shows the voltage waveform for this circuit arrangement:*

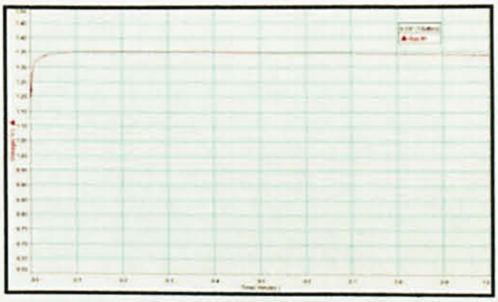


Figure 28: The voltage waveform across the light bulb for parallel connection between ultracapacitor (1000 miliFarad) and battery for the first one minute for one manganese battery (refer Appendix C.3 for full page view)

iii. combination of 1.5V battery and 1500 miliFarad ultracapacitor

- *For this type of circuit arrangement, the voltage waveform shows that the average voltage across the load for the first one minute is 1.250V. Figure 29 below shows the voltage waveform for this circuit arrangement:*

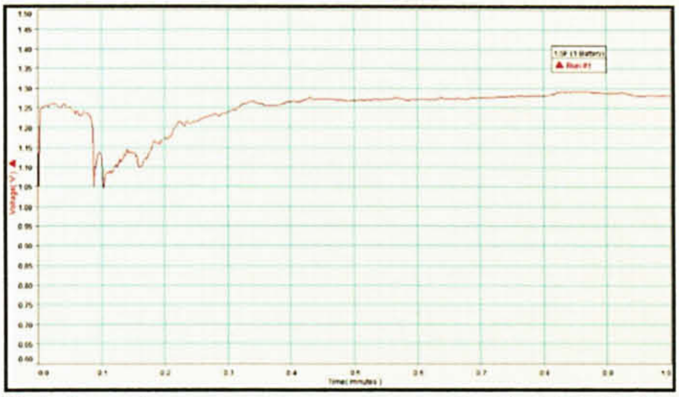


Figure 29: The voltage waveform across the light bulb for parallel connection between ultracapacitor (1500 miliFarad) and battery for the first one minute for one manganese battery (refer Appendix C.4 for full page view)

iv. combination of 1.5V battery and 22000 miliFarad ultracapacitor

- *For this type of circuit arrangement, the voltage waveform shows that the average voltage across the load for the first one minute is 0.982V. Figure 30 below shows the voltage waveform for this circuit arrangement:*

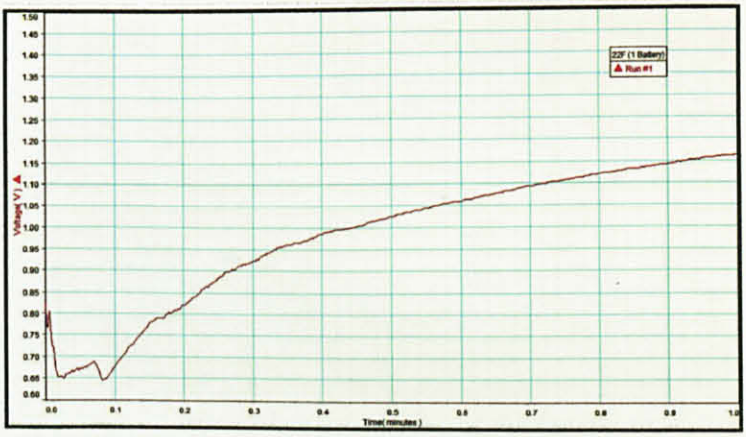


Figure 30: The voltage waveform across the light bulb for parallel connection between ultracapacitor (22000 miliFarad) and battery for the first one minute for one manganese battery (refer Appendix C.5 for full page view)

4.2.2.2 Two Manganese Batteries Circuit Arrangement

For this type of circuit arrangement, two manganese batteries with voltage rated at 3.0V (1.5V x 2) is used as the voltage supply and charging source for the ultracapacitor as well as to the light bulb as DC load. The results for this type of circuit arrangement are as follows:

a) Stand-alone battery

For this type of circuit arrangement, the voltage waveform shows that the average voltage across the load for the first one minute is 2.692V. Figure 31 below shows the voltage waveform for stand-alone battery system:

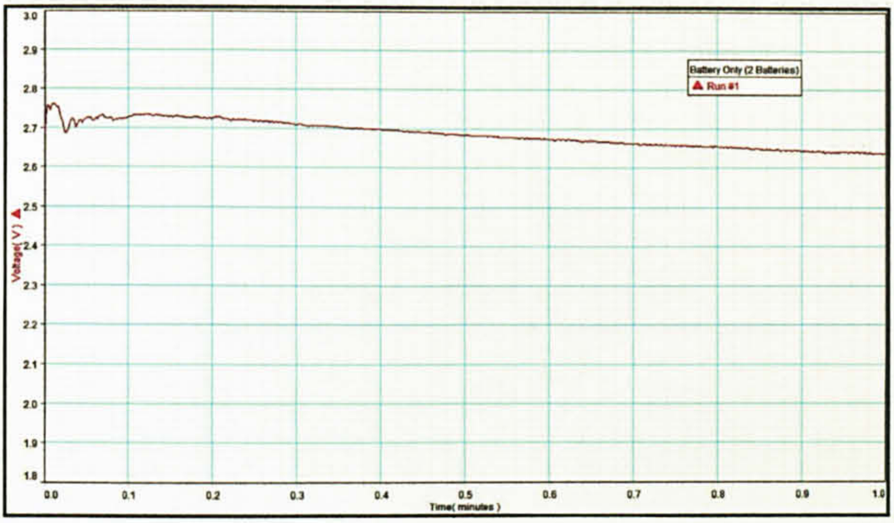


Figure 31: The voltage waveform across the light bulb for stand-alone battery circuit arrangement for the first one minute for two manganese batteries (refer Appendix D.1 for full page view)

b) Series connection between ultracapacitor and batteries

For this type of circuit arrangement, the voltmeter value shown that there is no voltage (0V of voltage) across the light bulb

c) Parallel connection between ultracapacitor and batteries

i. combination of 3.0V battery (1.5V x 2) and 330 miliFarad ultracapacitor

- *For this type of circuit arrangement, the voltage waveform shows that the average voltage across the load for the first one minute is 2.727V. Figure 32 below shows the voltage waveform for this circuit arrangement:*

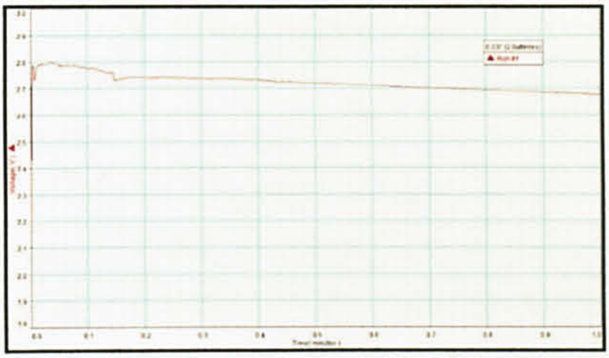


Figure 32: The voltage waveform across the light bulb for parallel connection between ultracapacitor (330 miliFarad) and battery for the first one minute for two manganese batteries (refer Appendix D.2 for full page view)

ii. combination of 3.0V battery (1.5V x 2) and 1000 miliFarad ultracapacitor

- *For this type of circuit arrangement, the voltage waveform shows that the average voltage across the load for the first one minute is 2.876V. Figure 33 below shows the voltage waveform for this circuit arrangement:*

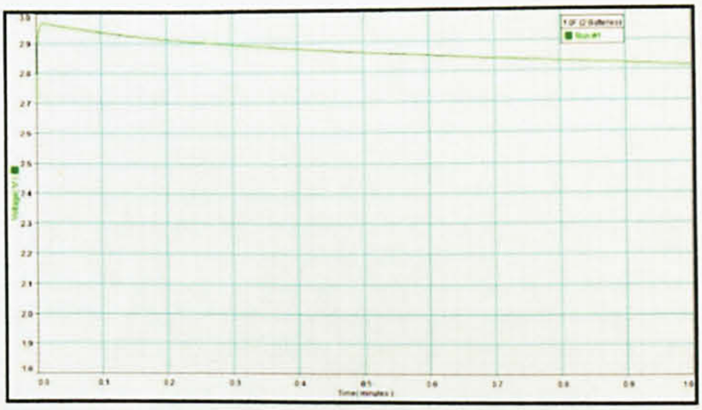


Figure 33: The voltage waveform across the light bulb for parallel connection between ultracapacitor (1000 miliFarad) and battery for the first one minute for two manganese batteries (refer Appendix D.3 for full page view)

iii. combination of 3.0V battery (1.5V x 2)and 1500 miliFarad ultracapacitor

- *For this type of circuit arrangement, the voltage waveform shows that the average voltage across the load for the first one minute is 2.344V. Figure 16 below shows the voltage waveform for this circuit arrangement:*

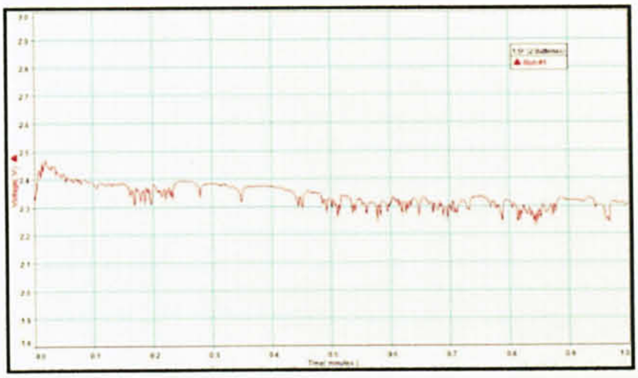


Figure 34: The voltage waveform across the light bulb for parallel connection between ultracapacitor (1500 miliFarad) and battery for the first one minute for two manganese batteries (refer Appendix D.4 for full page view)

iv. combination of 3.0V battery (1.5V x 2) and 22000 miliFarad ultracapacitor

- *For this type of circuit arrangement, the voltage waveform shows that the average voltage across the load for the first one minute is 2.553V. Figure 16 below shows the voltage waveform for this circuit arrangement:*

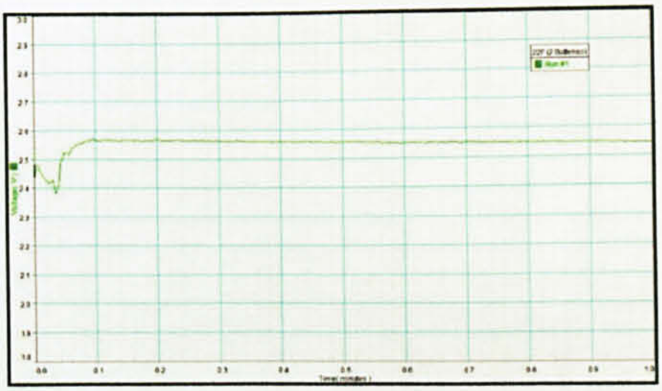


Figure 35: The voltage waveform across the light bulb for parallel connection between ultracapacitor (22000 miliFarad) and battery for the first one minute for two manganese batteries (refer Appendix D.5 for full page view)

iii. *combination of 3.0V battery (1.5V x 2)and 1500 miliFarad ultracapacitor*

- *For this type of circuit arrangement, the voltage waveform shows that the average voltage across the load for the first one minute is 2.344V. Figure 16 below shows the voltage waveform for this circuit arrangement:*

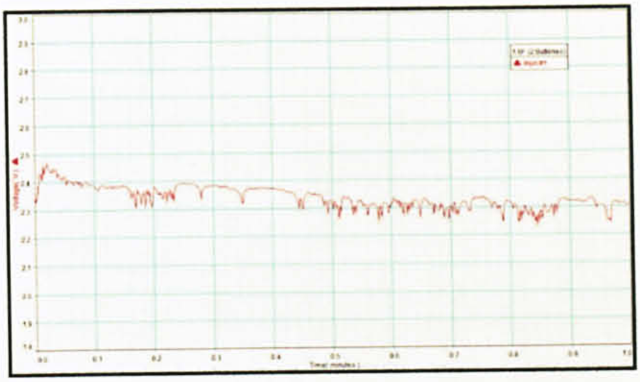


Figure 34: The voltage waveform across the light bulb for parallel connection between ultracapacitor (1500 miliFarad) and battery for the first one minute for two manganese batteries (refer Appendix D.4 for full page view)

iv. *combination of 3.0V battery (1.5V x 2) and 22000 miliFarad ultracapacitor*

- *For this type of circuit arrangement, the voltage waveform shows that the average voltage across the load for the first one minute is 2.553V. Figure 16 below shows the voltage waveform for this circuit arrangement:*

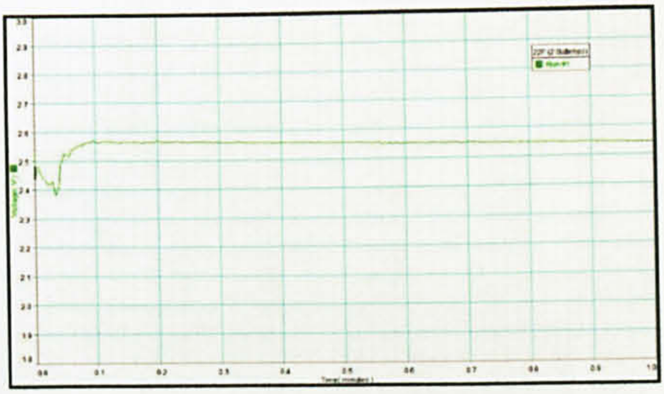


Figure 35: The voltage waveform across the light bulb for parallel connection between ultracapacitor (22000 miliFarad) and battery for the first one minute for two manganese batteries (refer Appendix D.5 for full page view)

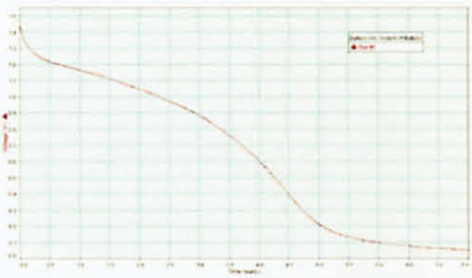
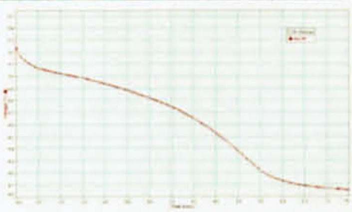
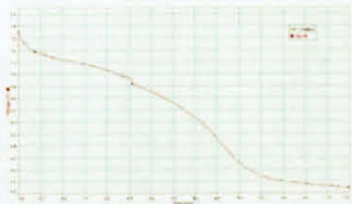
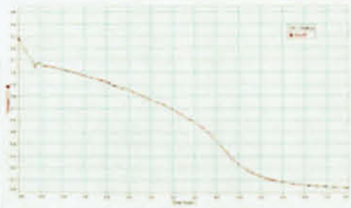
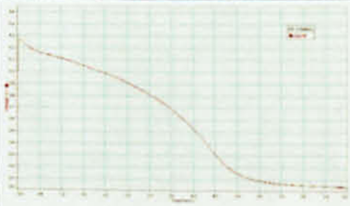
4.2.3 Summary of the Results

For this section, all the results obtained from part 4.21 and 4.22 will be summarized in the table for the ease of discussion part later on. These results include the runtime of the voltage across the DC load chosen as well as the instantaneous power or peak power in term of the voltage across the DC load chosen for the first one minute for both 1 manganese battery and 2 manganese batteries.

4.2.3.1 One Manganese Battery Circuit Arrangement

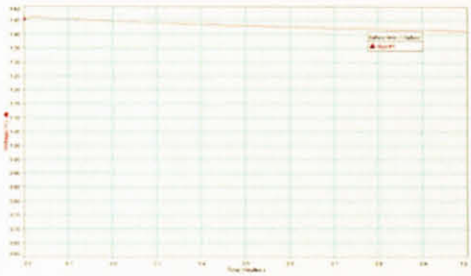
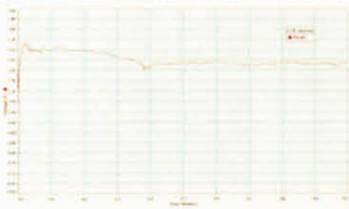
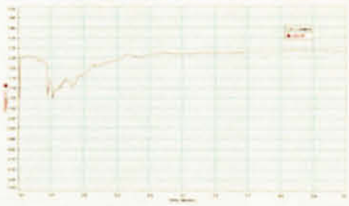
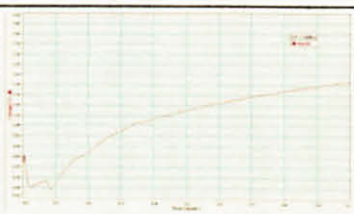
a) Runtime of the voltage across DC load in voltage (V)

Table 3: The summary of the runtime of the voltage across DC load in voltage for the circuit arrangement of one manganese battery with sampling time of 7.5 hours

Circuit arrangement	*Waveform*		*Voltage value at hour 7.5 (V)*
Stand-alone battery			0.049
Parallel connection between ultracapacitor and battery	330 miliFarad		0.051
	1000 miliFarad		0.046
	1500 miliFarad		0.036
	22000 miliFarad		0.034

b) Instantaneous power / Peak power for the first one minute in voltage (V)

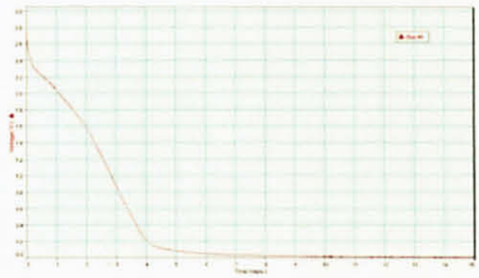
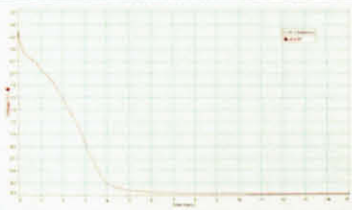
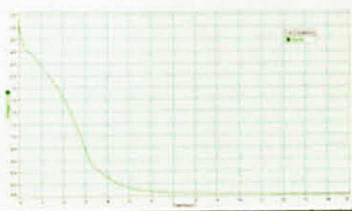
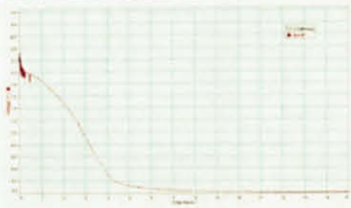
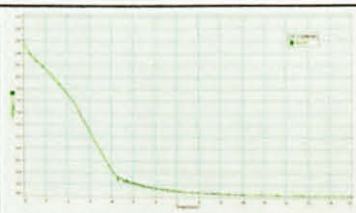
Table 4: The summary of the instantaneous power or peak power provided to the DC load in voltage for the circuit arrangement of one manganese battery with sampling time of 1 minute

Circuit arrangement	*Waveform*		*Average voltage value for the first one minute (V)*
Stand-alone battery			1.238
Parallel connection between ultracapacitor and battery	330 miliFarad		1.252
	1000 miliFarad		1.349
	1500 miliFarad		1.250
	22000 miliFarad		0.982

4.2.3.2 Two Manganese Battery Circuit Arrangement

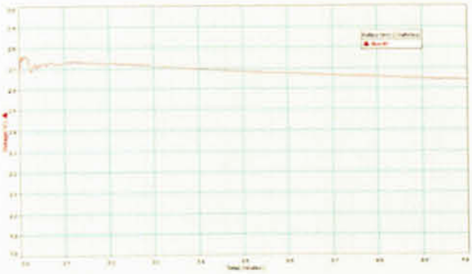
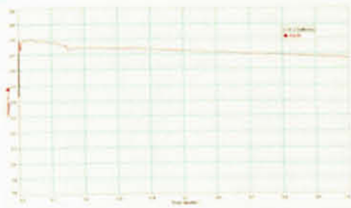
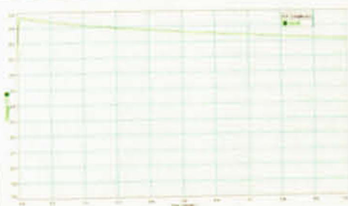
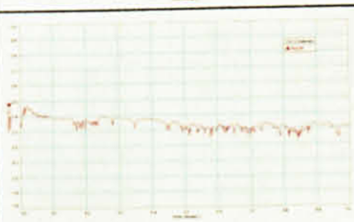
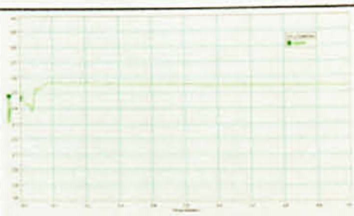
a) Runtime of the voltage across DC load in voltage (V)

Table 5: The summary of the runtime of the voltage across DC load in voltage for the circuit arrangement of two manganese batteries with sampling time of 15 hours

Circuit arrangement	*Waveform*		*Voltage value at hour 15 (V)*
Stand-alone battery			0.007
Parallel connection between ultracapacitor and battery	330 miliFarad		0.007
	1000 miliFarad		0.016
	1500 miliFarad		0.007
	22000 miliFarad		0.025

b) Instantaneous power / Peak power for the first one minute in voltage (V)

Table 6: The summary of the instantaneous power or peak power provided to the DC load in voltage for the circuit arrangement of two manganese batteries with sampling time of 1 minute

Circuit arrangement		*Waveform*	*Average voltage value for the first one minute (V)*
Stand-alone battery			2.692
Parallel connection between ultracapacitor and battery	330 miliFarad		2.727
	1000 miliFarad		2.876
	1500 miliFarad		2.553
	22000 miliFarad		2.344

After all the results have been summarized, the calculation of the factor of every result will be compared to the result of stand-alone battery circuit diagram because we want to see the comparison between the circuit with ultracapacitor and the circuit without ultracapacitor.

4.3 Discussion

Based on the results obtained in the previous section (section 4.2), this section will discuss each type of the experimental circuit arrangements used as well as the different capacitance values and quantity of manganese battery connected into the circuit respectively.

4.3.1 Analysis of the Runtime in Voltage Across the Load

In this section, the result for stand-alone battery circuit arrangement will be the base value and will be put in the denominator part while result for other circuit arrangements will be put at numerator part because we want to analyze by how many factor the circuit with ultracapacitor can affect the runtime in term of voltage of the DC load chosen for both 1 manganese battery and 2 manganese batteries. The factor with value of greater than 1 will showed the improvement while the factor with value that is equal or less than 1 will showed that there is no any improvement. The equation of the calculation is shown below:

$$Factor = \frac{Value\ of\ others\ circuit\ arrangement}{Value\ of\ stand\ alone\ battery\ circuit\ arrangement}$$

a) One Manganese Battery Circuit Arrangement

Table 7: The factor of the runtime in voltage across the DC load for parallel connection between ultracapacitor with battery compared to the connection of stand-alone battery for one manganese battery

Value of the voltage at hour 7.5 in Volt (V)			*Factor*
Parallel connection between ultracapacitor and battery		Stand-alone battery	
330 miliFarad	0.051 V	0.049 V	1.041
1000 miliFarad	0.046 V	0.049 V	0.939
1500 miliFarad	0.036 V	0.049 V	0.735
22000 miliFarad	0.034 V	0.049 V	0.694

From the value shown in the table above, the circuit arrangement of parallel connection between 330 miliFarad ultracapacitor and battery is capable to improve the runtime of the DC load chosen by the factor of 1.041. However, the circuit arrangement of parallel connection between other value of ultracapacitor (1000 miliFarad, 1500 miliFarad and 22000 miliFarad) and battery did not show any improvement of the runtime in term of the voltage across the DC load because the value of the factor is less than 1. Thus, the best arrangement of circuit to sustain a longer runtime for one manganese battery is the circuit with 330 miliFarad of ultracapacitor.

b) Two Manganese Batteries Circuit Arrangement

Table 8: The factor of the runtime in voltage across the DC load for parallel connection between ultracapacitor with battery compared to the connection of stand-alone battery for two manganese batteries

Value of the voltage at hour 15 in Volt (V)			*Factor*
Parallel connection between ultracapacitor and battery		Stand-alone battery	
330 miliFarad	0.007 V	0.007 V	1
1000 miliFarad	0.016 V	0.007 V	2.286
1500 miliFarad	0.007 V	0.007 V	1
22000 miliFarad	0.025 V	0.007 V	3.571

From the value shown in the table above, the circuit arrangement of parallel connection between 1000 miliFarad and 22000 miliFarad of ultracapacitor with two manganese batteries is capable to improve the runtime of the DC load chosen by the factor of 2.286 and 3.571 respectively. However, the circuit arrangement of parallel connection between 330 miliFarad and 1500 miliFarad of ultracapacitor with two manganese batteries did not show any improvement of the runtime in term of the voltage across the DC load because the value of the factor is equal to 1. Thus, the best arrangement of circuit to sustain a longer runtime for two manganese batteries is the circuit with 22000 miliFarad of ultracapacitor because it has the bigger factor compared to circuit with 1000 miliFarad of ultracapacitor.

4.3.2 Analysis of the Instantaneous Power or Peak Power in Voltage Across The Load

Similar with section 4.3.1, the result for stand-alone battery circuit arrangement will be the base value and will be put in the denominator part while result for other circuit arrangements will be put at numerator part because we want to analyze by how many factor the circuit with ultracapacitor can affect the instantaneous power or peak power (in term of voltage) provided to the DC load chosen for the first one minute for both 1 manganese battery and 2 manganese batteries. The factor with value of more than 1 will showed the improvement while the factor with value is equal or less than 1 will showed that there is no any improvement.

a) One Manganese Battery Circuit Arrangement

Table 9: The factor of the instantaneous power or peak power provided to the DC load in voltage for the first one minute for one manganese battery

Value of the average voltage for the first one minute in Volt (V)			*Factor*
Parallel connection between ultracapacitor and battery		Stand-alone battery	
330 miliFarad	1.252 V	1.238 V	1.011
1000 miliFarad	1.349 V	1.238 V	1.090
1500 miliFarad	1.250 V	1.238 V	1.010
22000 miliFarad	0.982 V	1.238 V	0.793

From the value shown in the table above, the circuit arrangement of parallel connection between 330 miliFarad, 1000 miliFarad and 1500 miliFarad of ultracapacitor and one manganese battery is capable to provide the instantaneous power or peak power for the first one minute to the DC load chosen by the factor of 1.011, 1.090 and 1.010 respectively. However, the circuit arrangement of parallel connection between 22000 miliFarad of ultracapacitor and one manganese battery is not capable to provide instantaneous power or peak power voltage across the DC load higher than the average voltage for the first one minute provided from stand-alone battery circuit arrangement because the value of the factor is less than 1 which is 0.793. Thus, the best arrangement of circuit to provide instantaneous power or peak power for the first one minute in term of average voltage for one manganese battery is the circuit with 330 miliFarad of ultracapacitor.

b) Two Manganese Batteries Circuit Arrangement

Table 10: The factor of the instantaneous power or peak power provided to the DC load in voltage for the first one minute for two manganese batteries

Value of the average voltage for the first one minute in Volt (V)			*Factor*
Parallel connection between ultracapacitor and battery		Stand-alone battery	
330 miliFarad	2.727 V	2.692 V	1.013
1000 miliFarad	2.876 V	2.692 V	1.068
1500 miliFarad	2.553 V	2.692 V	0.948
22000 miliFarad	2.344 V	2.692 V	0.871

From the value shown in the table above, the circuit arrangement of parallel connection between 330 miliFarad and 1000 miliFarad of ultracapacitor and two manganese batteries is capable to provide the instantaneous power or peak power for the first one minute to the DC load chosen by the factor of 1.013 and 1.068 respectively. However, the circuit arrangement of parallel connection between 1500 miliFarad and 22000 miliFarad of ultracapacitor and two manganese batteries is not capable to provide instantaneous power or peak power voltage across the DC load higher than the average voltage for the first one minute provided from stand-alone battery circuit arrangement because the value of the factor is less than 1 which is 0.948 and 0.871 respectively. Thus, the best arrangement of circuit to provide instantaneous power or peak power for the first one minute in term of average voltage for two manganese batteries is the circuit with 1000 miliFarad of ultracapacitor.

4.3.3 Performances of Each Circuit Arrangement

For this section, the performances of each circuit arrangement will be summarized in a table to see the variation of the voltage across the DC load every half an hour in the case of parallel arrangement of one manganese battery with ultracapacitor and every hour in the case of parallel arrangement of two manganese batteries with ultracapacitor.

a) One Manganese Battery Circuit Arrangement

Table 11: The performance of each circuit arrangement in voltage for one manganese battery with interval time of 0.5 hour

Hour	*Circuit Arrangement*				
	Stand-alone battery	*Parallel connection between battery and ultracapacitor*			
		330 miliFarad	*1000 miliFarad*	*1500 miliFarad*	*22000 miliFarad*
0.0	1.436 V	1.149 V	1.260 V	1.100 V	0.825 V
0.5	1.215 V	1.066 V	1.172 V	1.066 V	1.162 V
1.0	1.162 V	1.021 V	1.120 V	1.021 V	1.113 V
1.5	1.111 V	0.985 V	1.080 V	0.972 V	1.055 V
2.0	1.046 V	0.939 V	1.032 V	0.922 V	0.988 V
2.5	0.973 V	0.886 V	0.965 V	0.850 V	0.909 V
3.0	0.883 V	0.820 V	0.855 V	0.772 V	0.816 V
3.5	0.762 V	0.745 V	0.757 V	0.690 V	0.688 V
4.0	0.605 V	0.651 V	0.632 V	0.582 V	0.527 V
4.5	0.396 V	0.528 V	0.460 V	0.425 V	0.312 V
5.0	0.215 V	0.377 V	0.254 V	0.234 V	0.150 V
5.5	0.129 V	0.221 V	0.151 V	0.131 V	0.089 V
6.0	0.096 V	0.128 V	0.103 V	0.085 V	0.063 V
6.5	0.078 V	0.087 V	0.078 V	0.062 V	0.050 V
7.0	0.062 V	0.066 V	0.059 V	0.046 V	0.041 V
7.5	0.049 V	0.051 V	0.046 V	0.036 V	0.034 V

b) Two Manganese Batteries Circuit Arrangement

Table 12: The performance of each circuit arrangement in voltage for two manganese batteries with interval time of 1 hour

Hour	*Circuit Arrangement*				
	Stand-alone battery	*Parallel connection between battery and ultracapacitor*			
		330 miliFarad	*1000 miliFarad*	*1500 miliFarad*	*22000 miliFarad*
0.0	2.683 V	2.692 V	2.887 V	2.352 V	2.531 V
1.0	2.039 V	2.078 V	2.163 V	1.857 V	2.120 V
2.0	1.585 V	1.589 V	1.637 V	1.492 V	1.722 V
3.0	0.862 V	0.860 V	0.793 V	0.933 V	1.112 V
4.0	0.214 V	0.197 V	0.320 V	0.321 V	0.455 V
5.0	0.079 V	0.084 V	0.128 V	0.123 V	0.237 V
6.0	0.045 V	0.051 V	0.073 V	0.075 V	0.140 V
7.0	0.032 V	0.035 V	0.047 V	0.051 V	0.097 V
8.0	0.022 V	0.027 V	0.038 V	0.035 V	0.070 V
9.0	0.018 V	0.020 V	0.030 V	0.025 V	0.055 V
10.0	0.014 V	0.016 V	0.026 V	0.020 V	0.043 V
11.0	0.012 V	0.012 V	0.023 V	0.015 V	0.037 V
12.0	0.009 V	0.012 V	0.021 V	0.013 V	0.032 V
13.0	0.007 V	0.009 V	0.020 V	0.010 V	0.029 V
14.0	0.007 V	0.009 V	0.017 V	0.009 V	0.025 V
15.0	0.007 V	0.007 V	0.016 V	0.007 V	0.025 V

4.3.4 Summary of the Each Circuit Arrangement's Analysis

a) Runtime (voltage) across the load

Table 13: The comparison of factor in term of runtime in voltage across DC load for both 1 manganese battery and 2 manganese batteries

Parallel connection between ultracapacitor and manganese battery		
Capacitance of ultracapacitor (miliFarad)	Factor	
	1 manganese battery	2 manganese batteries
330	1.041	1
1000	0.939	2.286
1500	0.735	1
22000	0.694	3.571

Table above shows the factor of each circuit arrangement of parallel connection between ultracapacitor and manganese battery compared to stand-alone battery circuit arrangement for both 1 manganese battery and 2 manganese batteries. The factor is varied based on the quantity of the voltage supply provided by the manganese battery as well as the value of the capacitance of ultracapacitor used. Besides the factor comparison, the waveform of each circuit arrangement also can be compared between each arrangement of the circuit. The Figures 36 and 37 below shows the waveform of voltage reading in each circuit for 1 manganese battery and two manganese batteries which is gathered into one graph respectively.

Figure 36 below shows the waveform for all circuit arrangement in term of runtime in voltage across the DC load for 7.5 hours. This waveform corresponding to 1 manganese battery connected in parallel with ultracapacitor.

While Figure 37 below shows the waveform for all circuit arrangement in term of runtime in voltage across the DC load for 7.5 hours. This waveform corresponding to 2 manganese batteries connected in parallel with ultracapacitor.

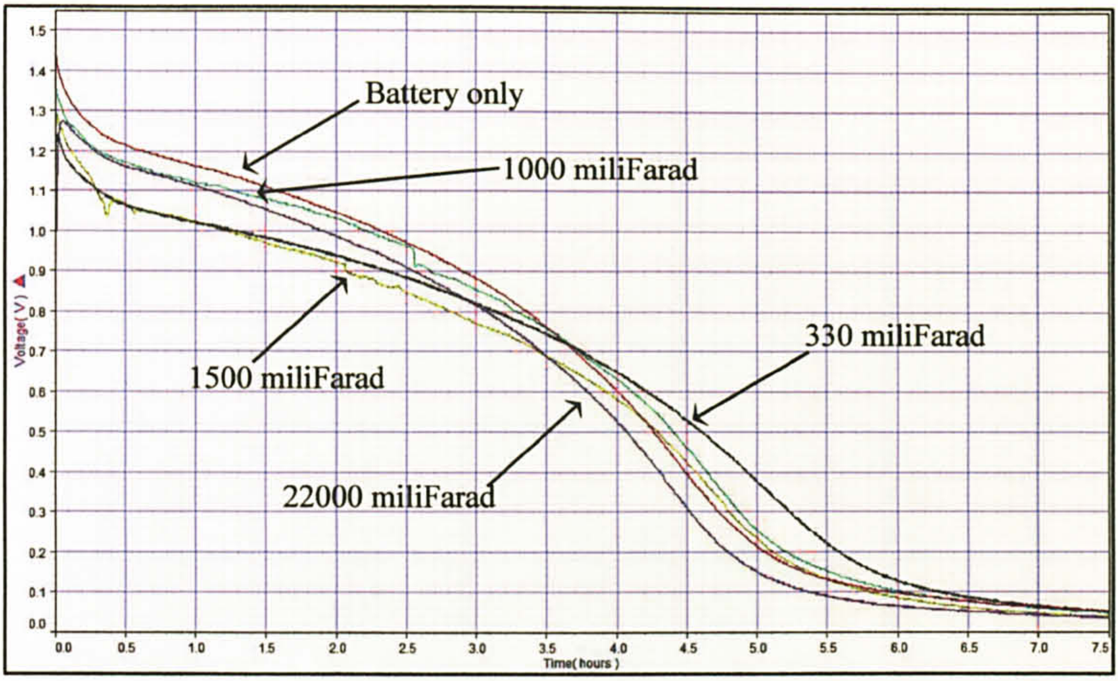


Figure 36: The comparison of every waveform for the voltage across the load for one manganese battery (refer Appendix E.1 for full page view)

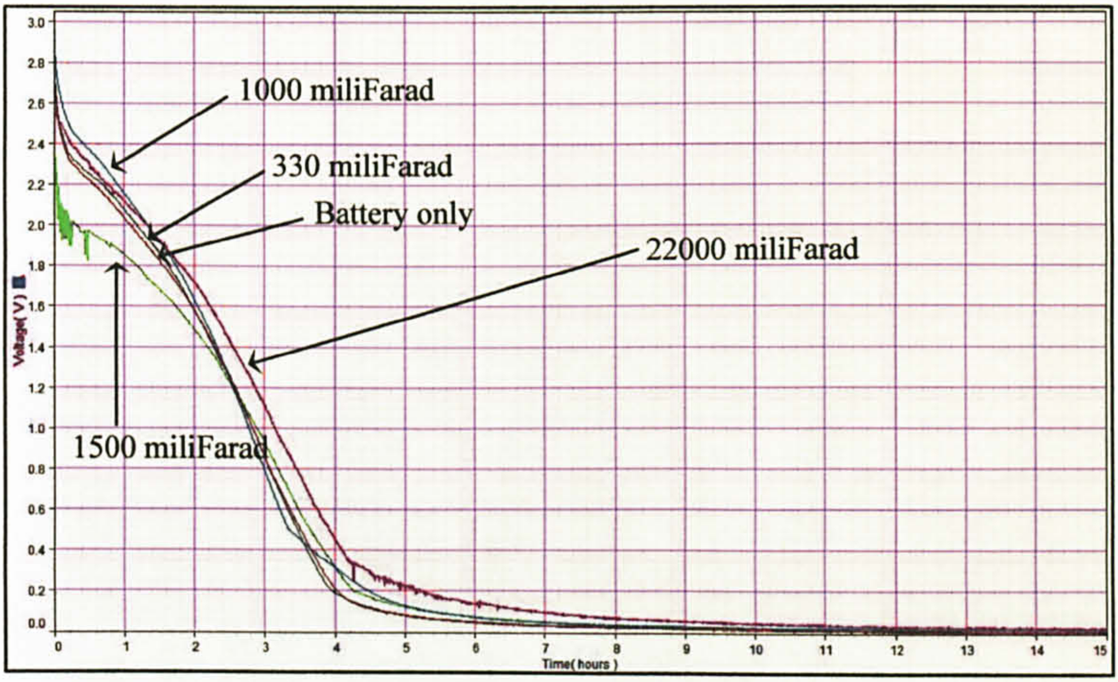


Figure 37: The comparison of every waveform for the voltage across the load for two manganese batteries (refer Appendix E.2 for full page view)

b) Instantaneous power / Peak power for the forst one minute in voltage (V)

Table 14: The comparison of factor for pulse power or peak power provided to the DC load in term of voltage for the first one minute for both 1 manganese battery and 2 manganese batteries

Parallel connection between ultracapacitor and manganese battery		
Capacitance of ultracapacitor (miliFarad)	Factor	
	1 manganese battery	2 manganese batteries
330	1.011	1.013
1000	1.090	1.068
1500	1.010	0.948
22000	0.793	0.871

Table above shows the factor of each circuit arrangement of parallel connection between ultracapacitor and manganese battery compared to stand-alone battery circuit arrangement for both 1 manganese battery and 2 manganese batteries. The factor is varied based on the quantity of the voltage supply provided by the manganese battery as well as the value of the capacitance of ultracapacitor used. Besides the factor comparison, the waveform of each circuit arrangement also can be compared between each arrangement of the circuit. The figures 38 and 39 below shows the waveform of voltage reading in each circuit for 1 manganese battery and two manganese batteries which is gathered into one graph respectively.

The Figure 38 below shows the waveform for all circuit arrangement in term of instantaneous power or peak power provided to the DC load for the first one minute. This waveform corresponding to 1 manganese battery connected in parallel with ultracapacitor.

While Figure 39 below shows the waveform for all circuit arrangement in term of instantaneous power or peak power provided to the DC load for the first one minute. This waveform corresponding to 2 manganese batteries connected in parallel with ultracapacitor.

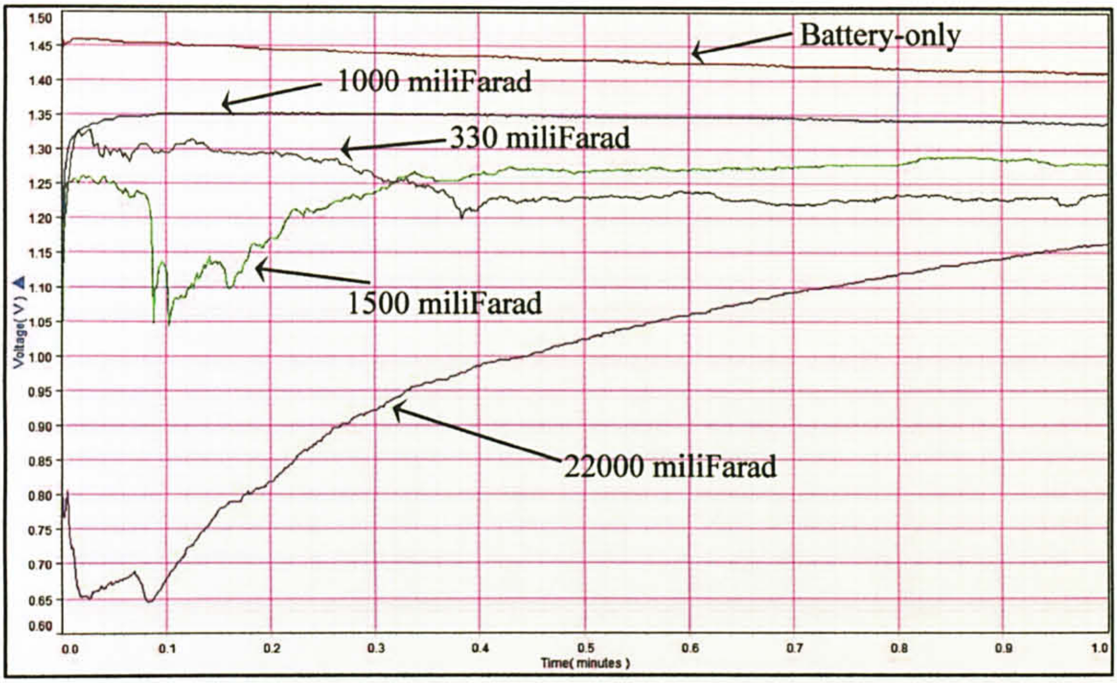


Figure 38: The comparison of every waveform for the first one minute in voltage that across the load for one manganese battery (refer Appendix F.1 for full page view)

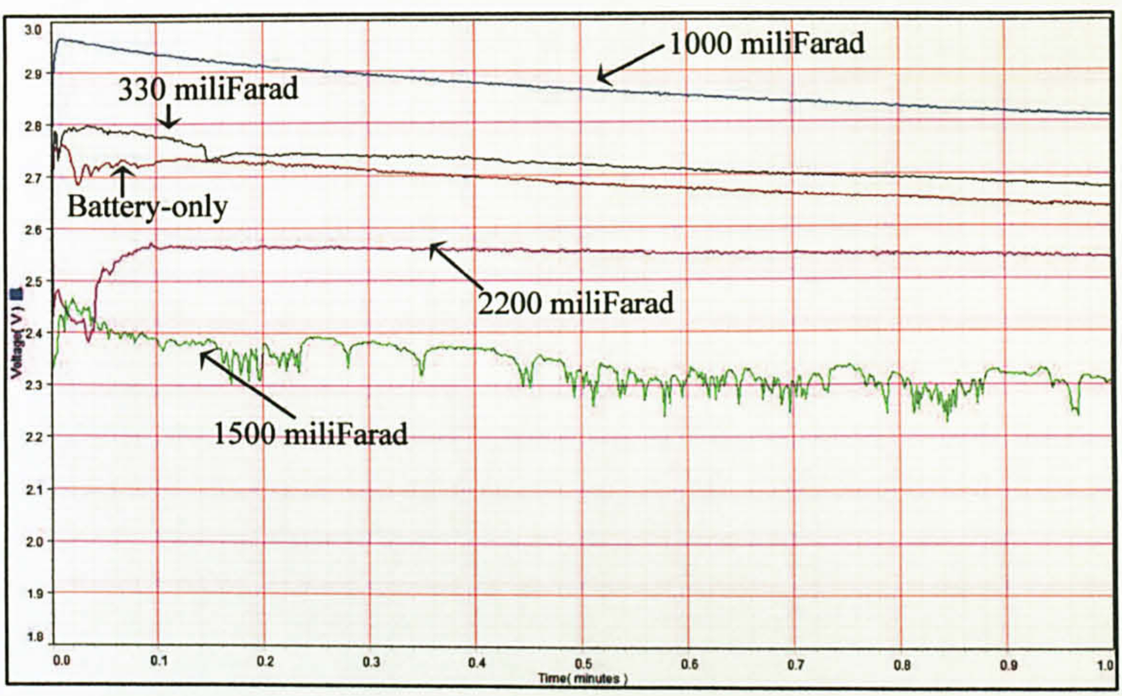


Figure 39: The comparison of every waveform for the first one minute in voltage that across the load for two manganese batteries (refer Appendix F.2 for full page view)

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

For this context of project, a complete circuitry system of a working prototype using ultracapacitor as energy storage device and pulsed power provider for peak power demand were theoretically examined and experimentally validated. By best combination of the battery and the ultracapacitor, a superior system was obtained. The energy storage and power capabilities of the ultracapacitor will allow it to act as a bridge between battery and ultracapacitor performance in order to extend the life of the battery.

This is proven with the combination of 2 manganese batteries connected in parallel with 22000 miliFarad capacitance of ultracapacitor which was capable to increasing the runtime of the devices or application chosen, in this case the light bulb by the factor of 3.571 compared to the circuit arrangement of stand-alone manganese battery (without ultracapacitor) with factor of 1.

Furthermore, the combination of 1000 miliFarad capacitance of ultracapacitor with 1 manganese battery in parallel arrangement is another proof which shows that ultracapacitor is capable in providing instantaneous power or peak power in terms of average voltage across the light bulb for first the one minute by the factor of 1.090 which was greater than the circuit arrangement without ultracapacitor with factor of 1.

This technology is new and typically designed to extend the life of battery and it is expected that it may be applicable for use in other devices.

5.2 Recommendation for Future Work

There are a few modifications and improvements that can be made in terms of the circuit arrangement, environmental surrounding conditions, development of the rate of change for each waveform and the frequency of the experimentation conducted in order to get the better results in the future. Some of those modifications and improvements are:

- combination of more than 2 batteries with the ultracapcitor. For instance, use 4 batteries for each ultracapacitor connected into the circuit to see the variation of the results
- conduct this experimentation in the same environmental surrounding conditions so that the external factor or external errors can be neglected
- run each experimentation more than once to obtain a more precise finding
- develop rate of change calculation for every waveform for further analysis in terms of performances
- design the circuit which combines the best feature of voltage runtime and instantaneous power / peak power
- the reference should be the circuit arrangement of using ordinary or standard capacitor
- the main parameter should be the current flow consideration
- analyze the current charging and discharging of the ultracapacitor

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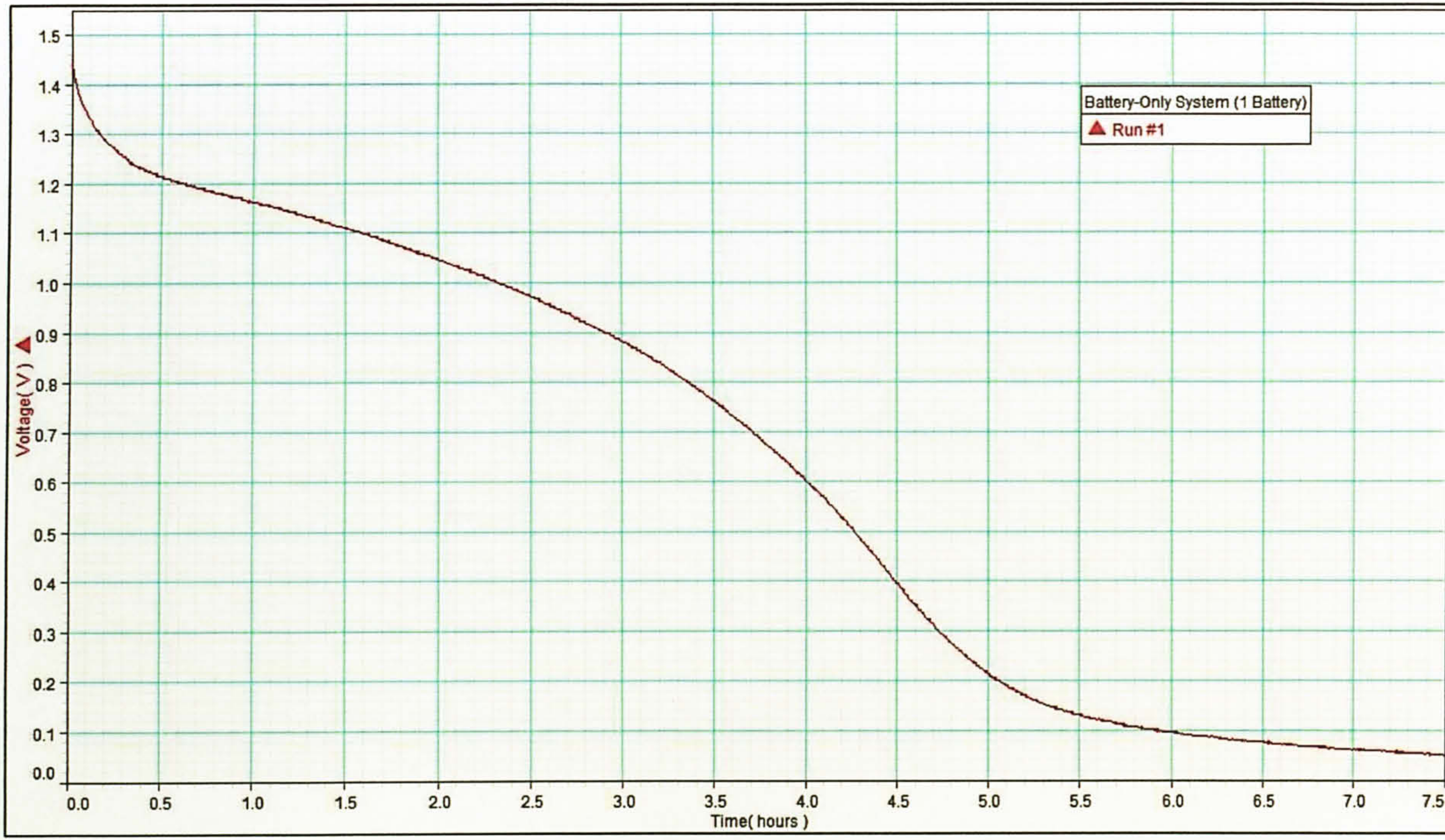
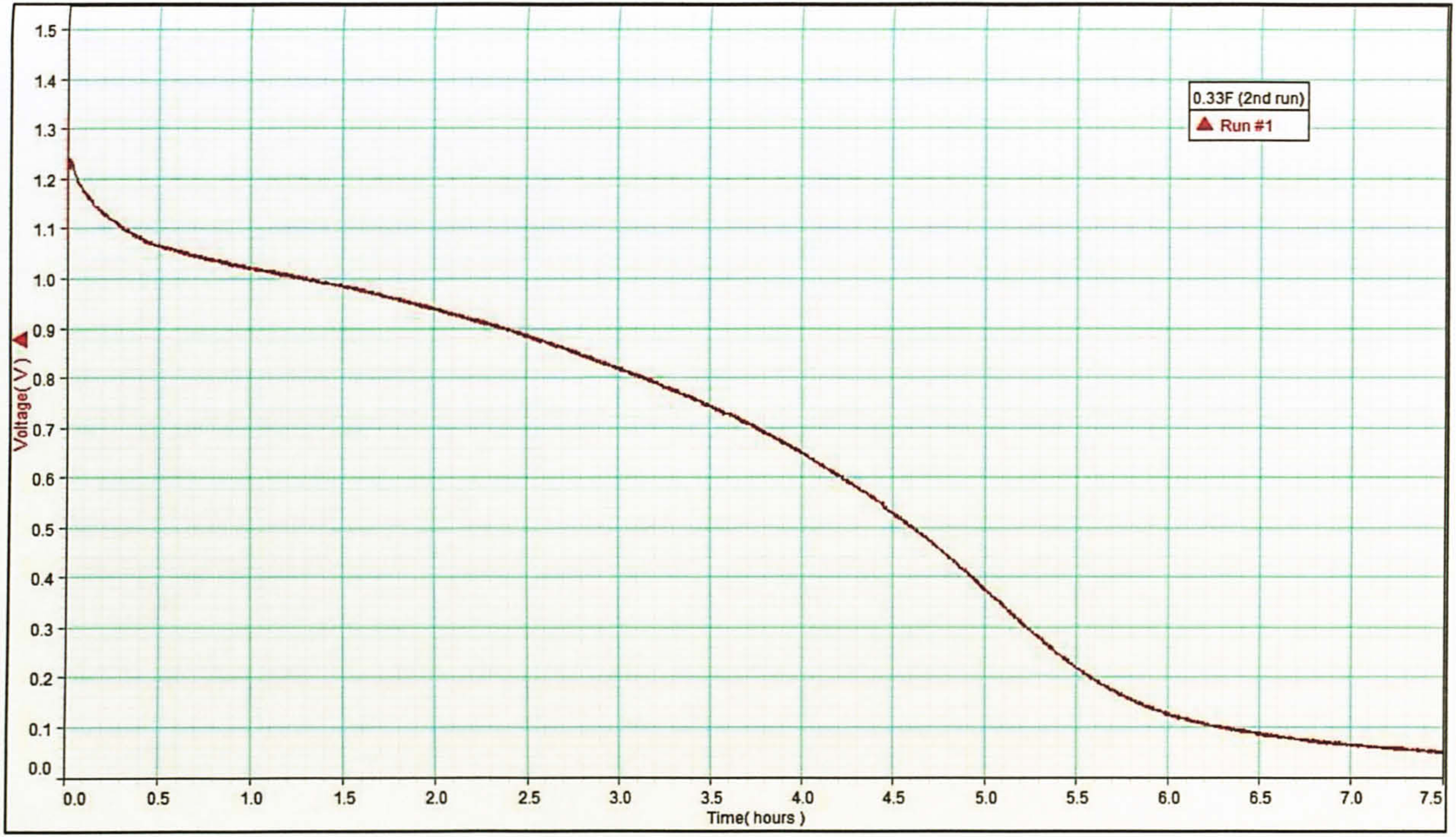
APPENDICES

APPENDIX A

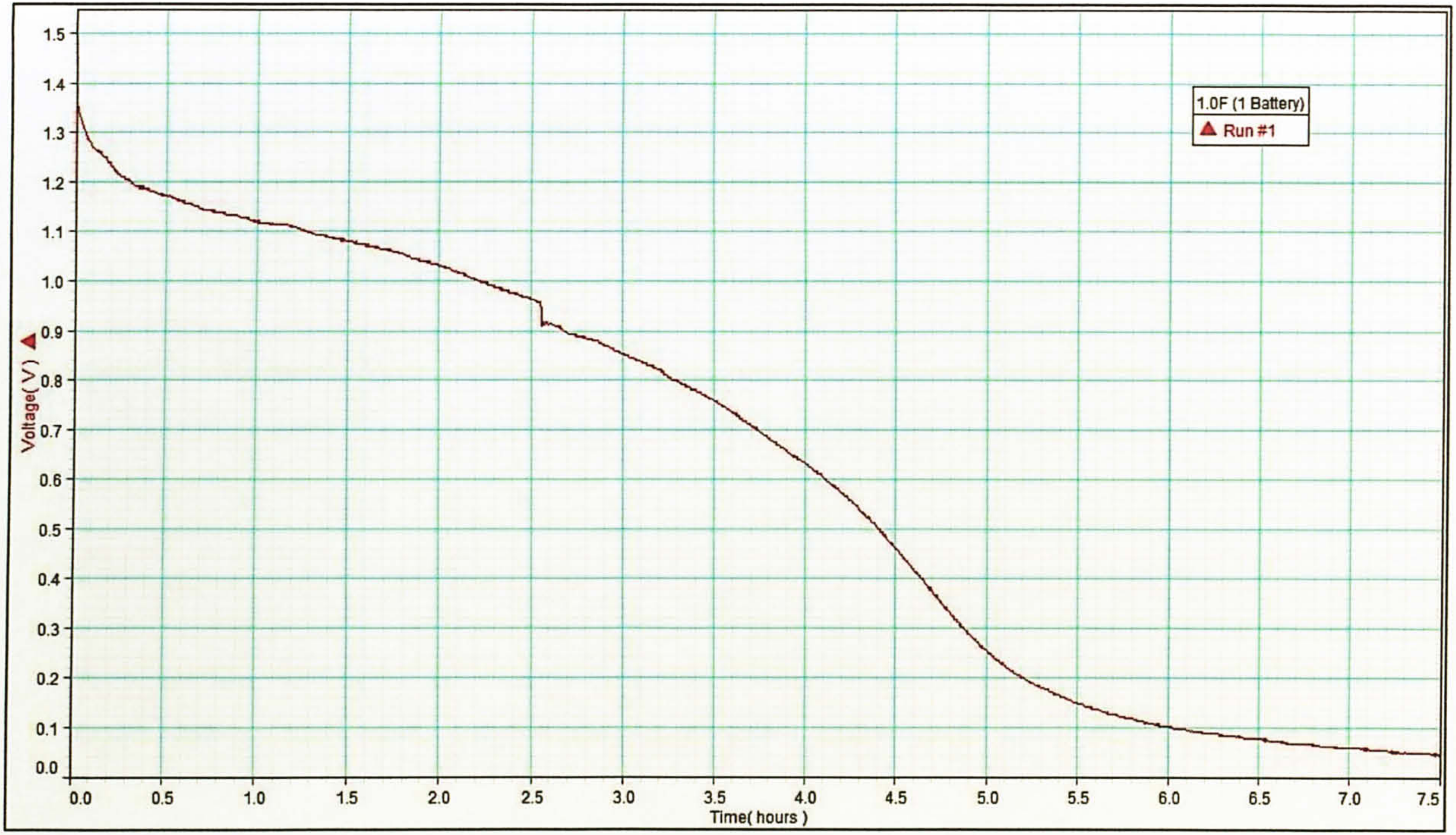
VOLTAGE WAVEFORMS FOR ONE MANGANESE BATTERY CIRCUIT ARRANGEMENT FOR THE RUNTIME OF THE DEVICES



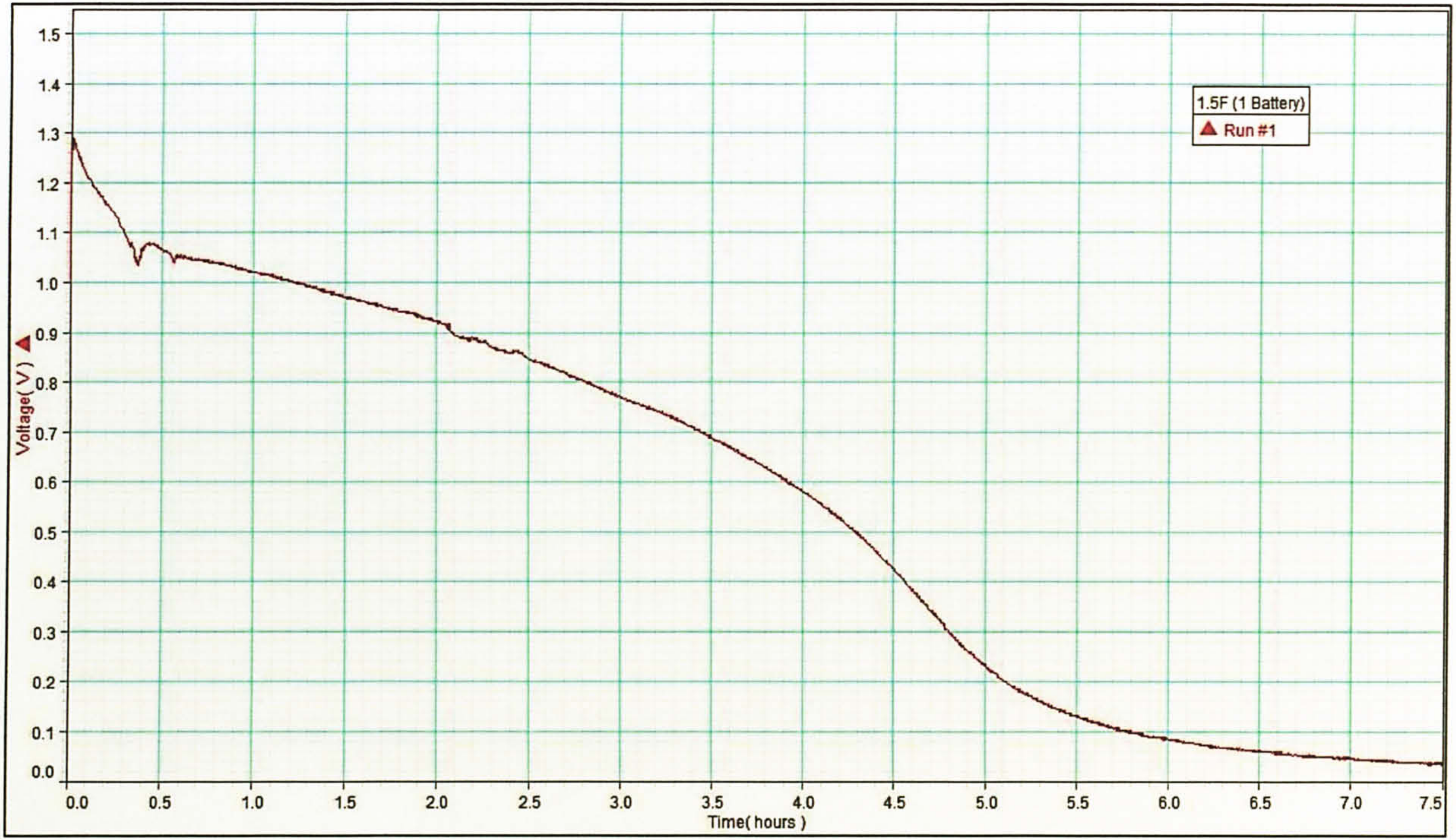
Appendix A.1: Full page view of the voltage waveform across the light bulb for stand-alone battery circuit arrangement for one manganese battery



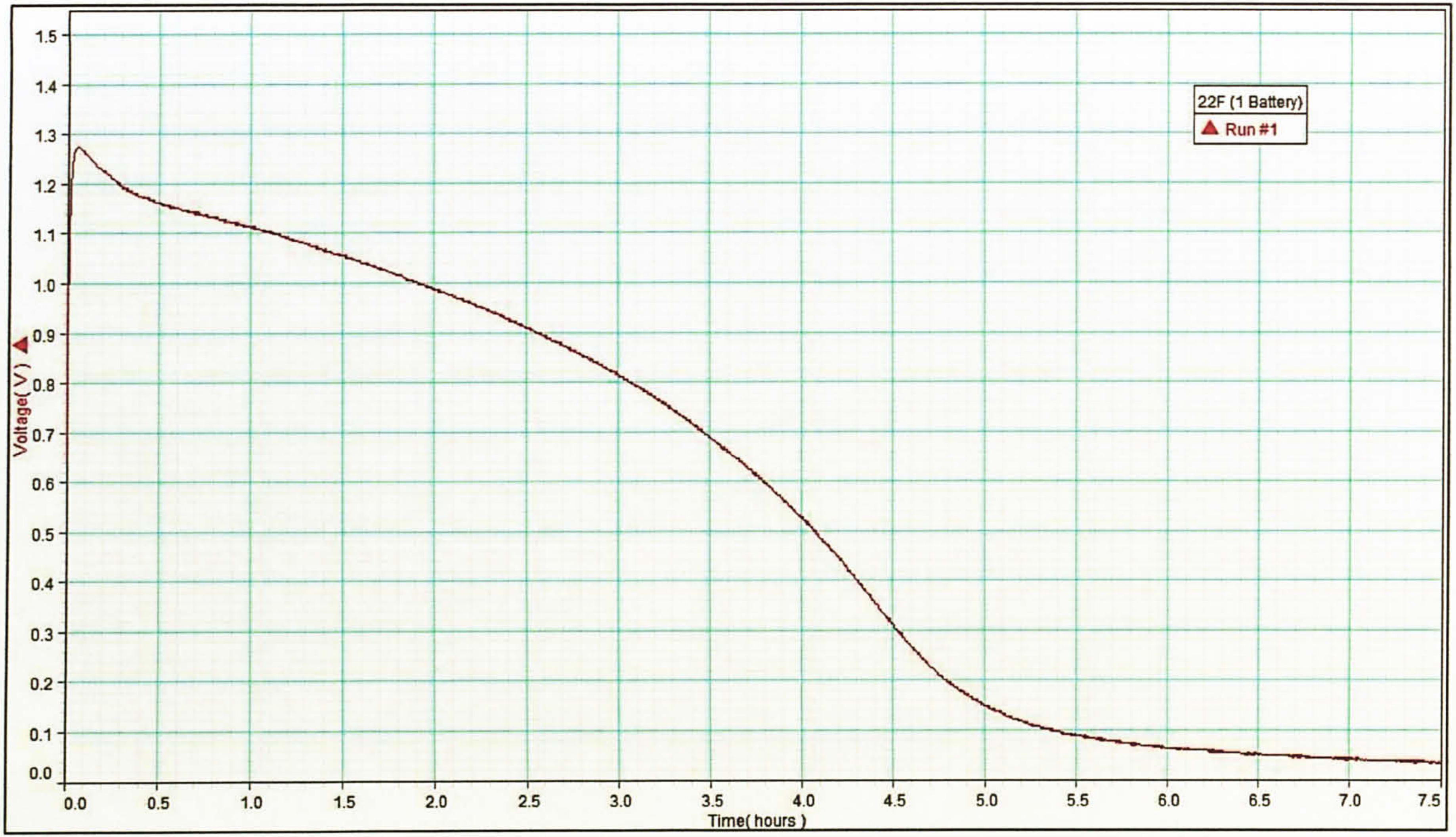
Appendix A.2: Full page view of the voltage waveform across the light bulb for parallel connection between ultracapacitor (330 miliFarad) and battery for one manganese battery



Appendix A.3: Full page view of the voltage waveform across the light bulb for parallel connection between ultracapacitor (1000 miliFarad) and battery for one manganese battery



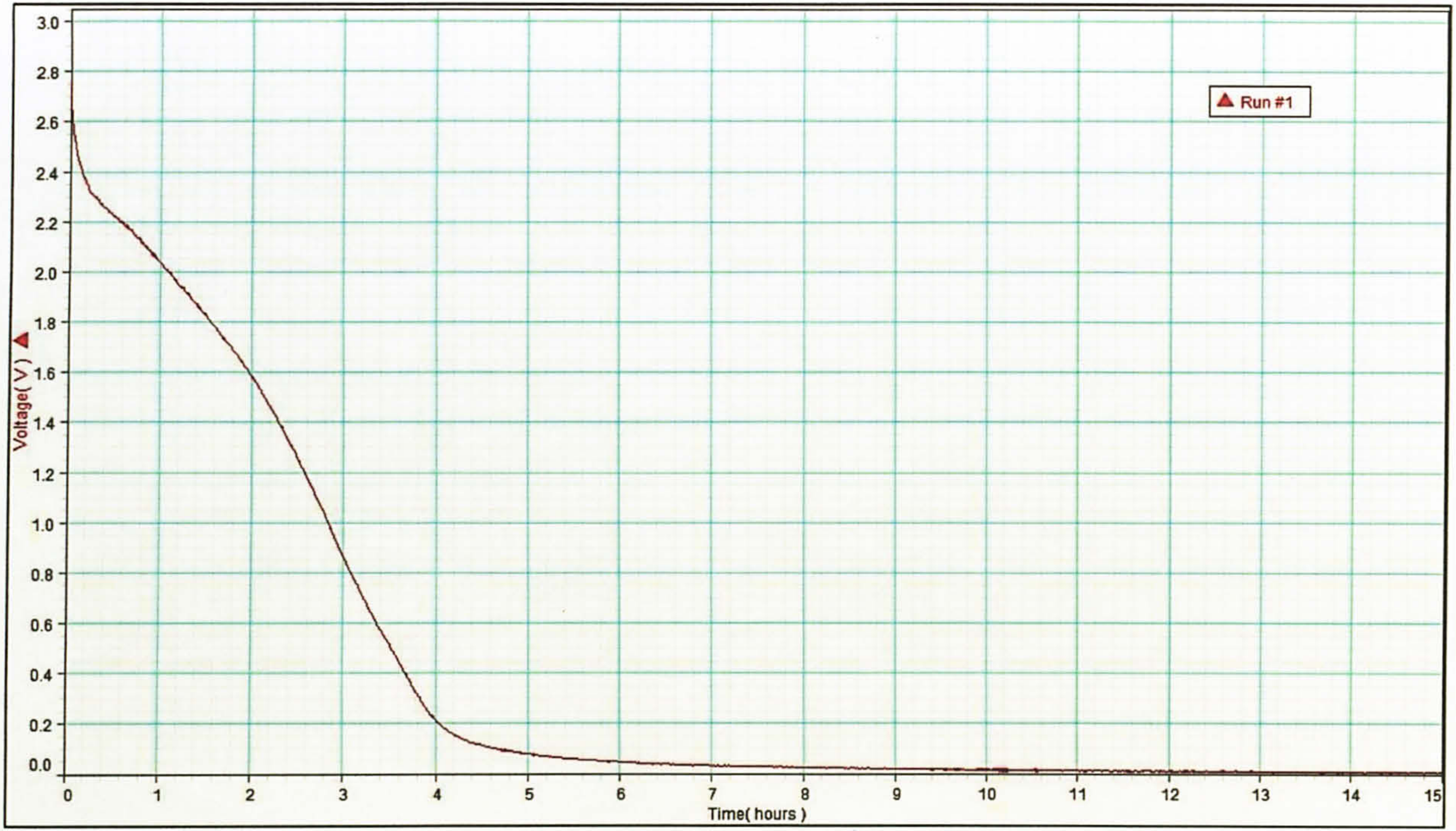
Appendix A.4: Full page view of the voltage waveform across the light bulb for parallel connection between ultracapacitor (1500 miliFarad) and battery for one manganese battery



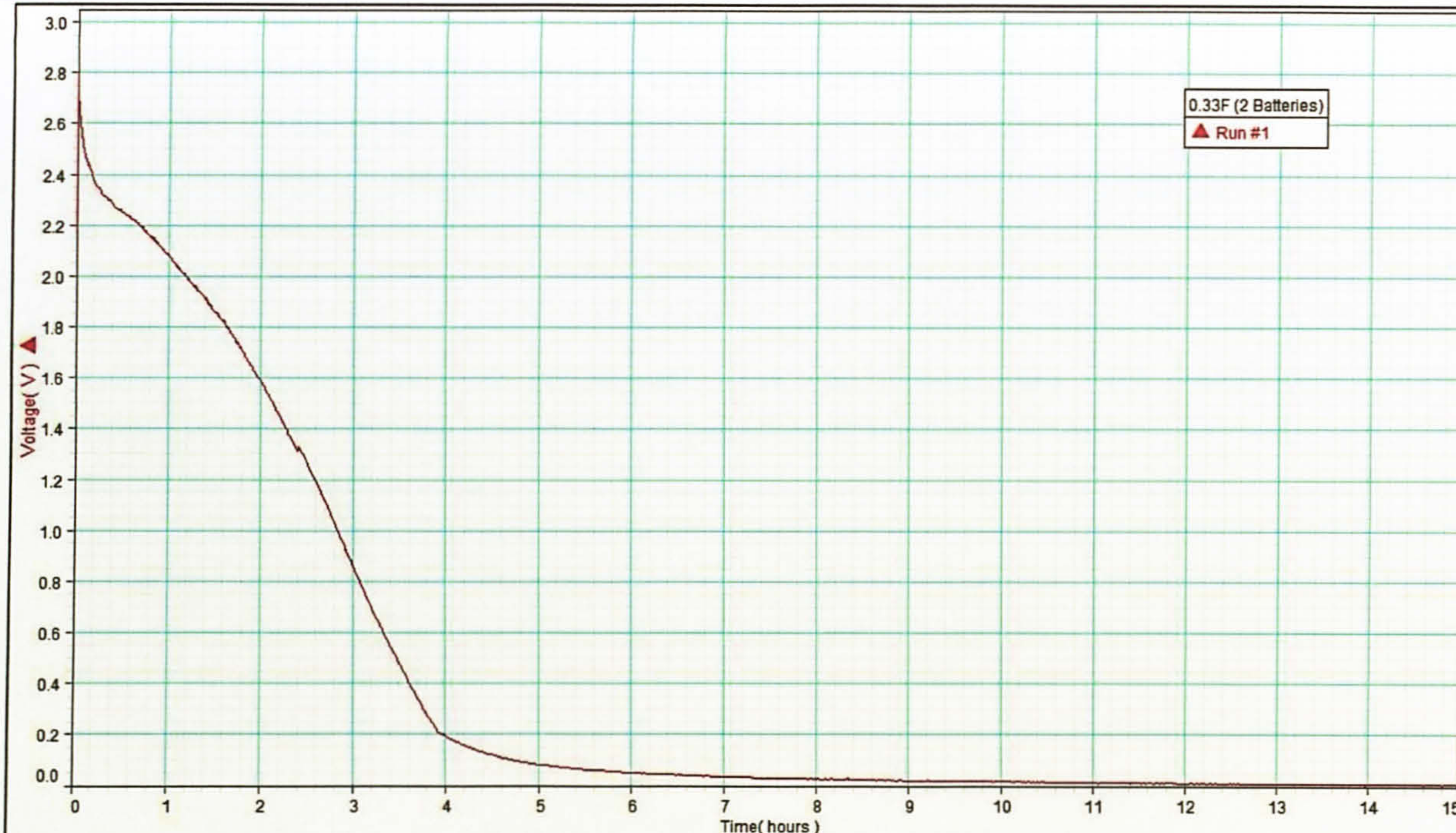
Appendix A.5: Full page view of the voltage waveform across the light bulb for parallel connection between ultracapacitor (22000 miliFarad) and battery for one manganese battery

APPENDIX B

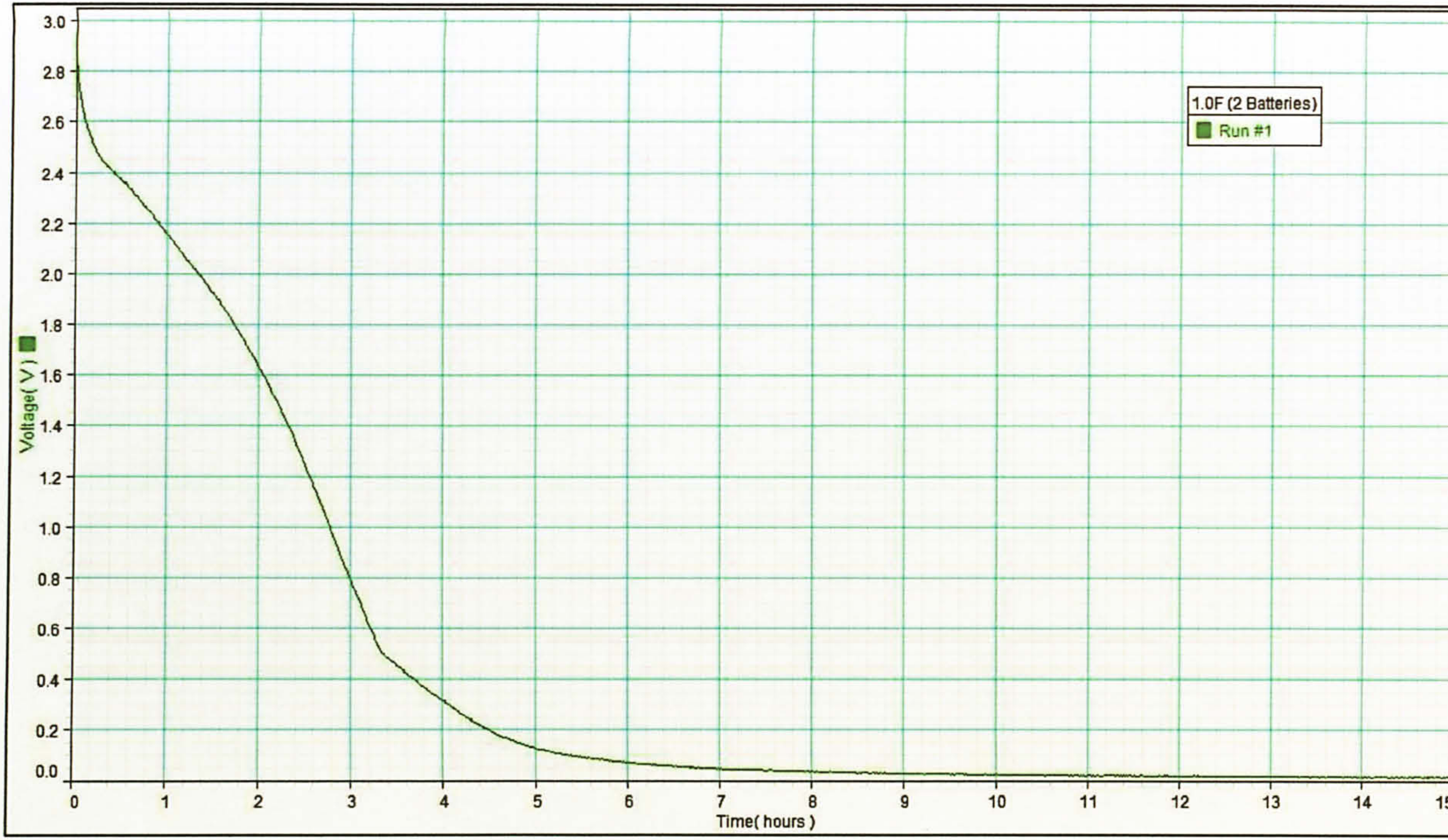
VOLTAGE WAVEFORMS FOR TWO MANGANESE BATTERIES CIRCUIT ARRANGEMENT FOR THE RUNTIME OF THE DEVICES



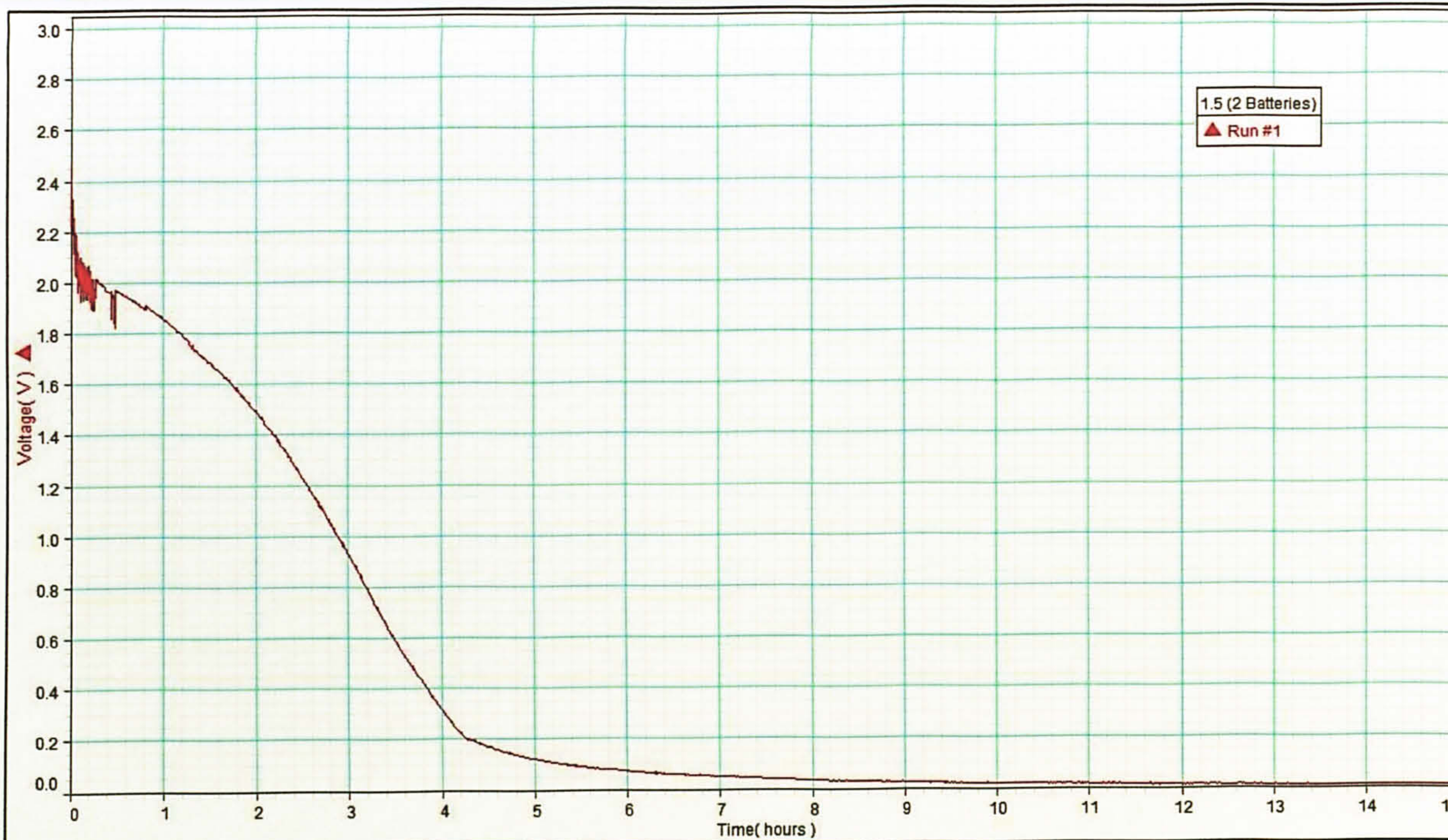
Appendix B.1: Full page view of the voltage waveform across the light bulb for stand-alone battery circuit arrangement for two manganese batteries



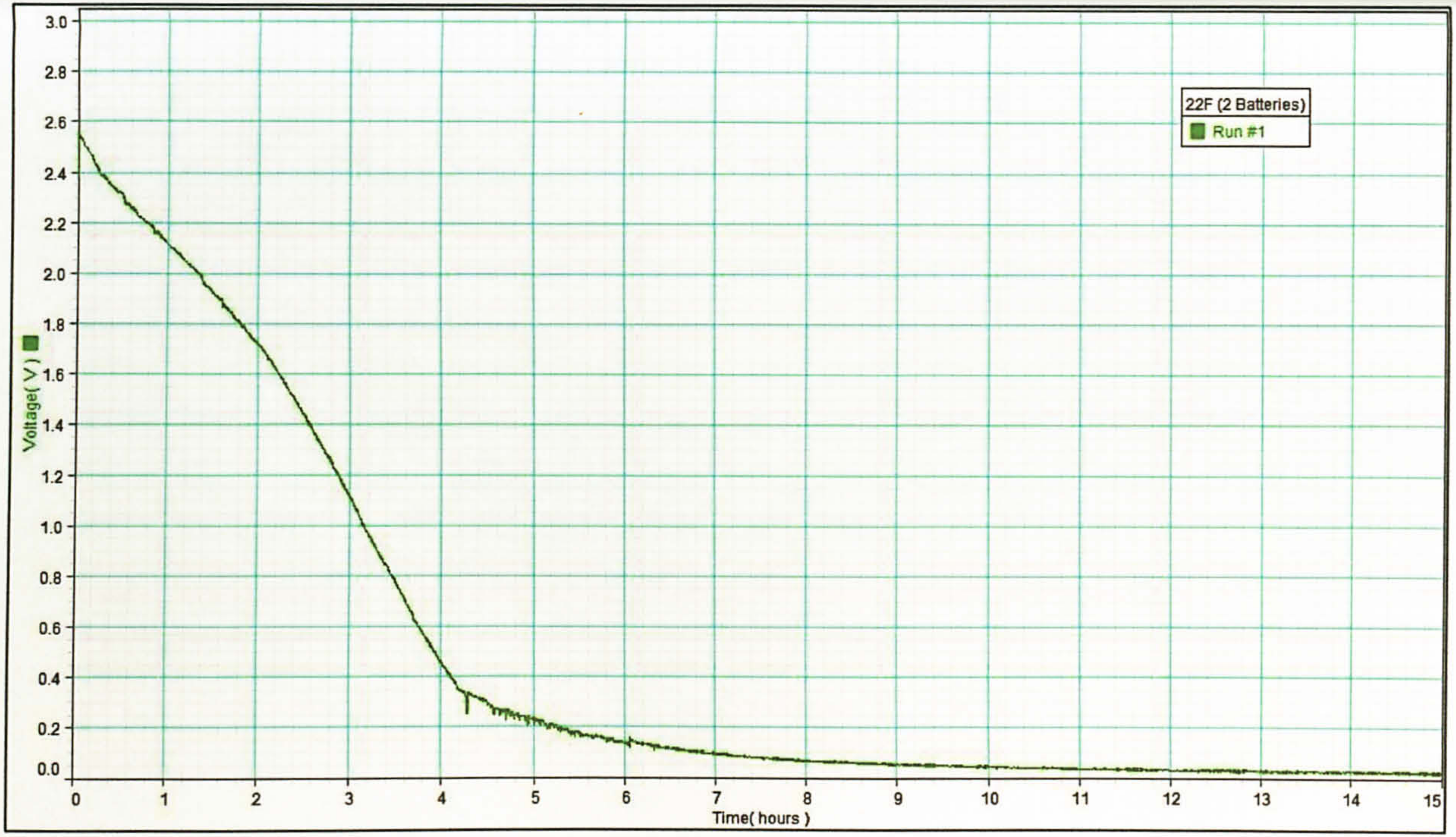
Appendix B.2: Full page view of the voltage waveform across the light bulb for parallel connection between ultracapacitor (330 miliFarad) and battery for two manganese batteries



Appendix B.3: Full page view of the voltage waveform across the light bulb for parallel connection between ultracapacitor (1000 miliFarad) and battery for two manganese batteries



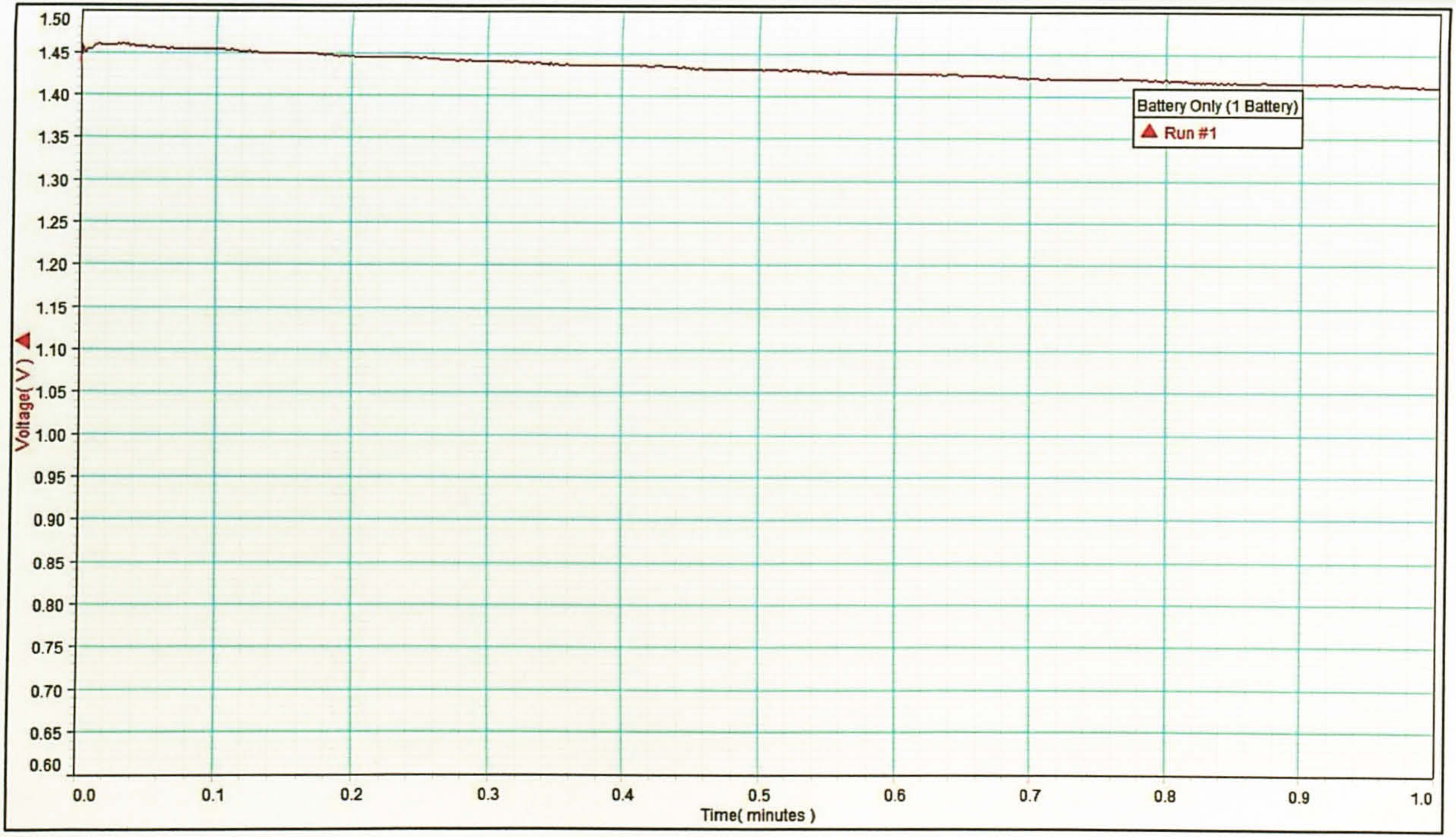
Appendix B.4: Full page view of the voltage waveform across the light bulb for parallel connection between ultracapacitor (1500 miliFarad) and battery for two manganese batteries



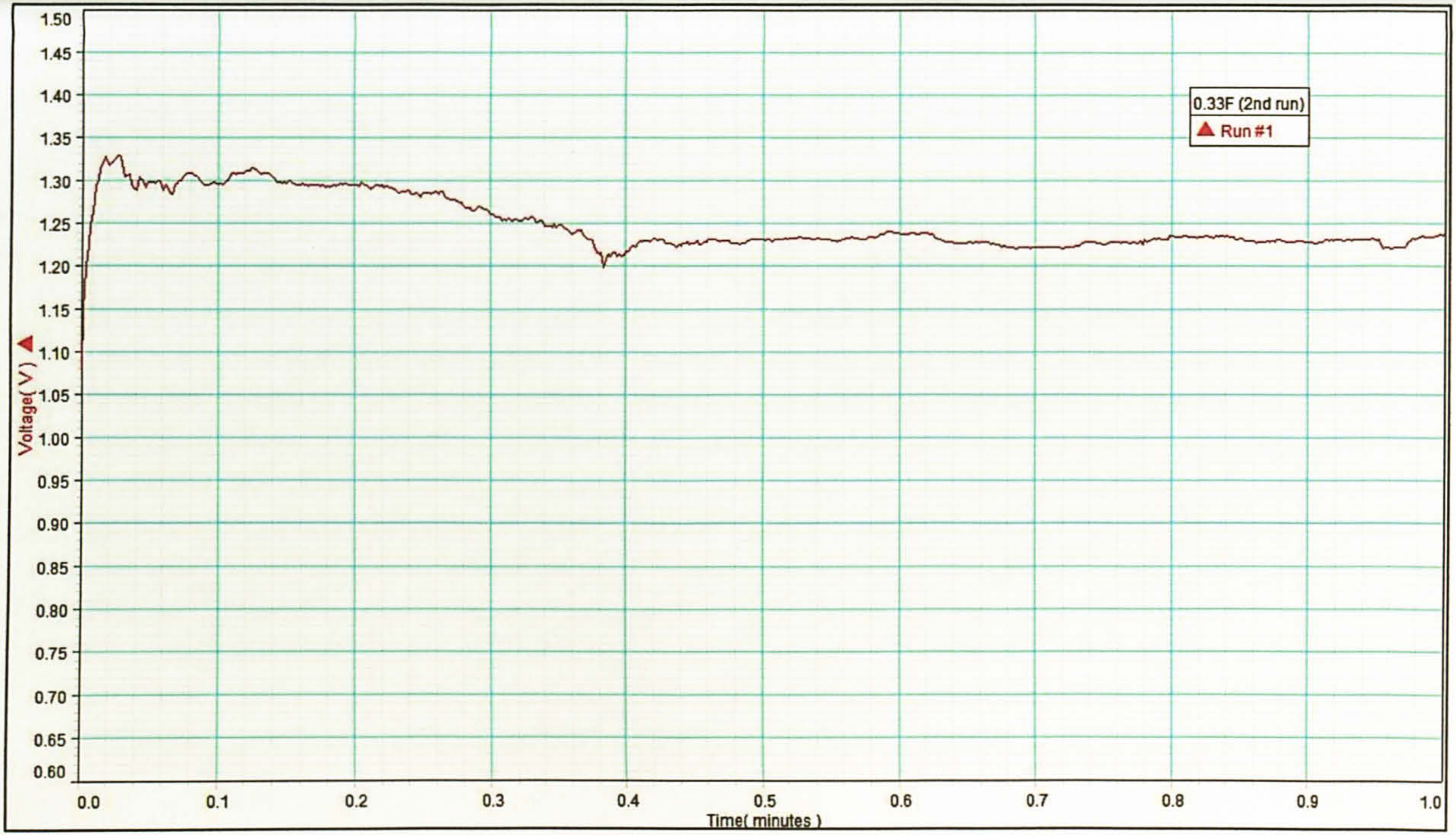
Appendix B.5: Full page view of the voltage waveform across the light bulb for parallel connection between ultracapacitor (22000 miliFarad) and battery for two manganese batteries

APPENDIX C

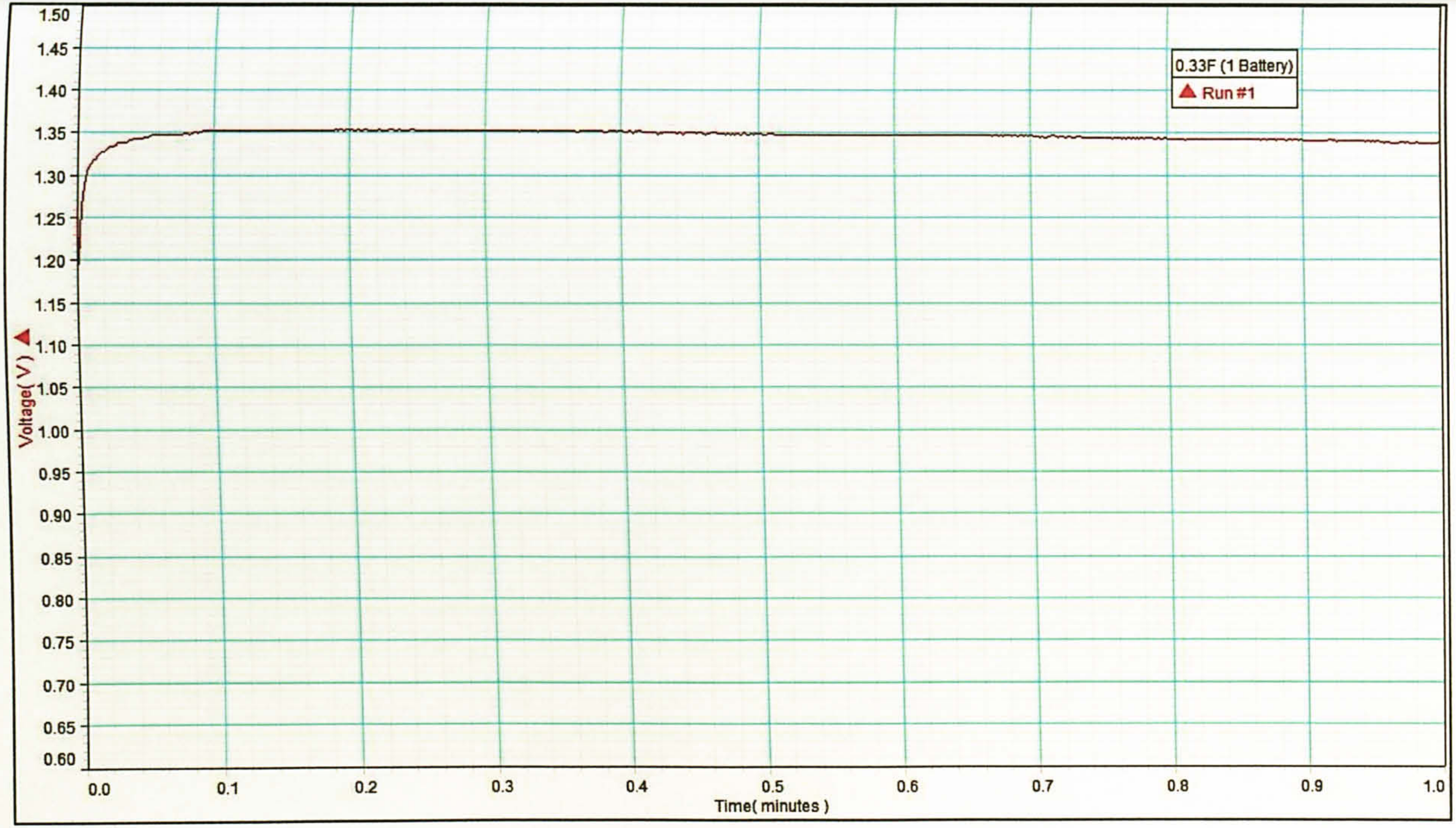
VOLTAGE WAVEFORMS FOR ONE MANGANESE BATTERY CIRCUIT ARRANGEMENT FOR THE INSTANTANEOUS POWER OR PEAK POWER PROVIDED TO DEVICES



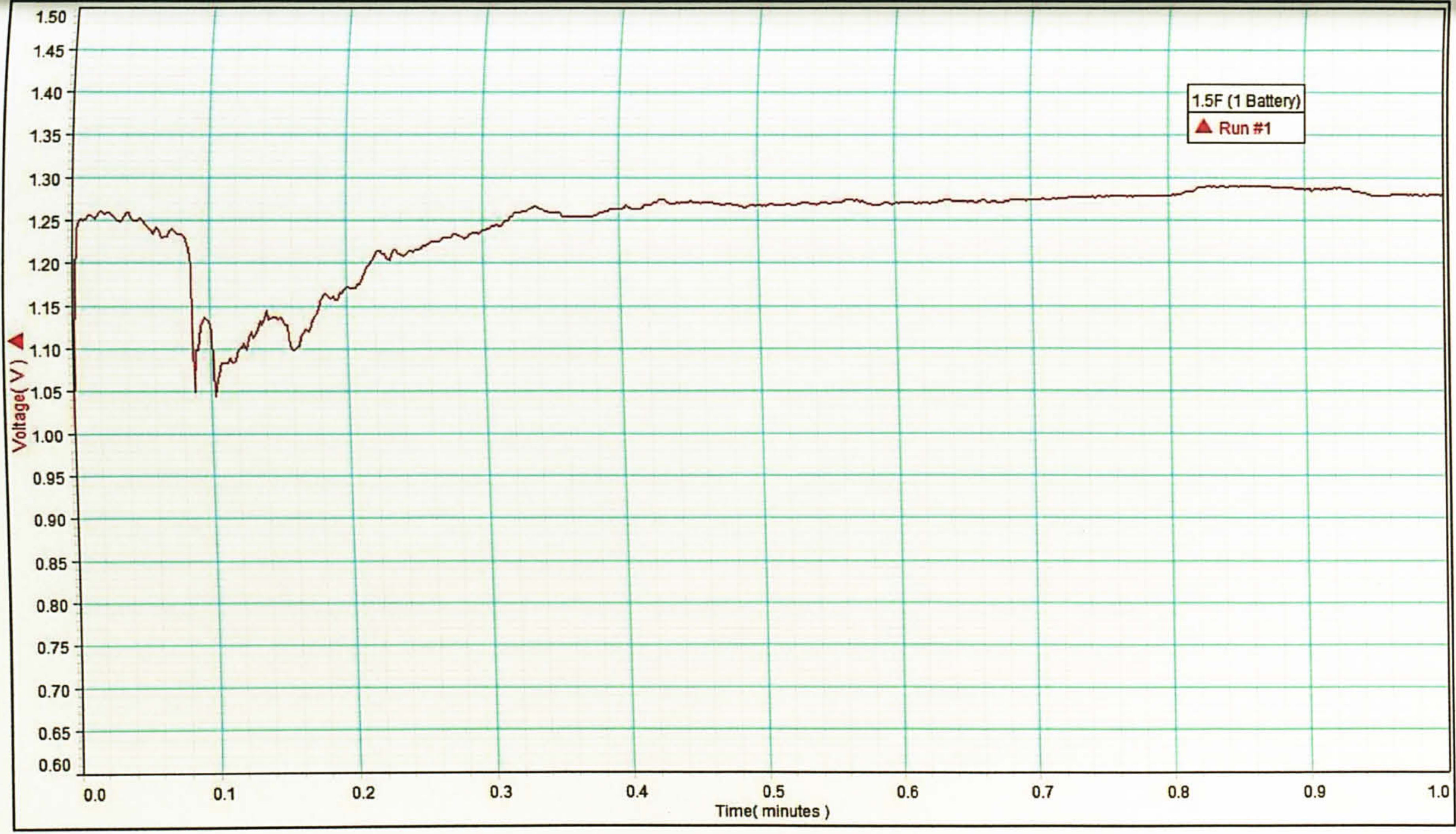
Appendix C.1: Full page view of the voltage waveform across the light bulb for stand-alone battery circuit arrangement for the first one minute for one manganese battery



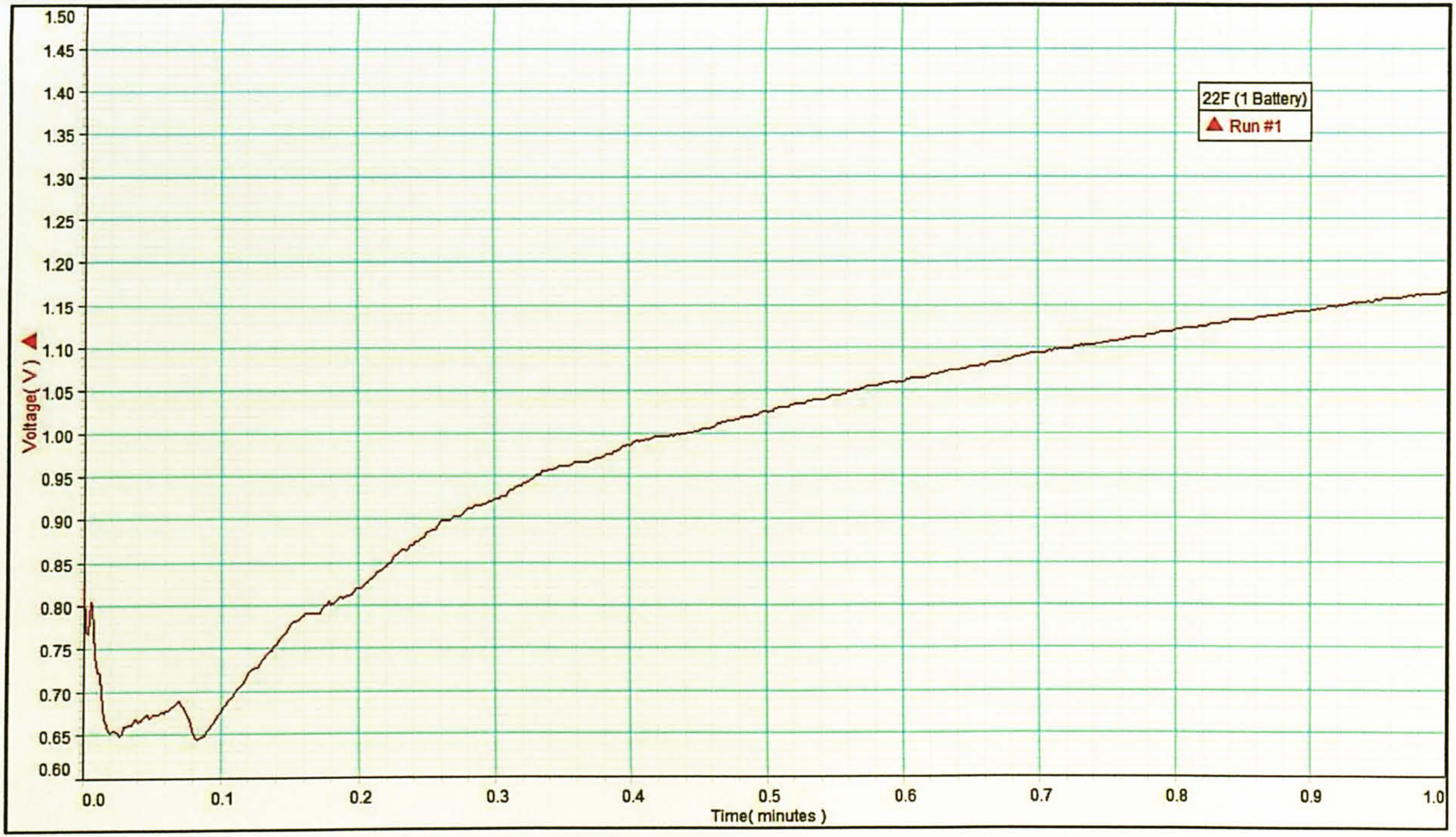
Appendix C.2: Full page view of the voltage waveform across the light bulb for parallel connection between ultracapacitor (330 miliFarad) and battery for the first one minute for one manganese battery



Appendix C.3: Full page view of the voltage waveform across the light bulb for parallel connection between ultracapacitor (1000 miliFarad) and battery for the first one minute for one manganese battery



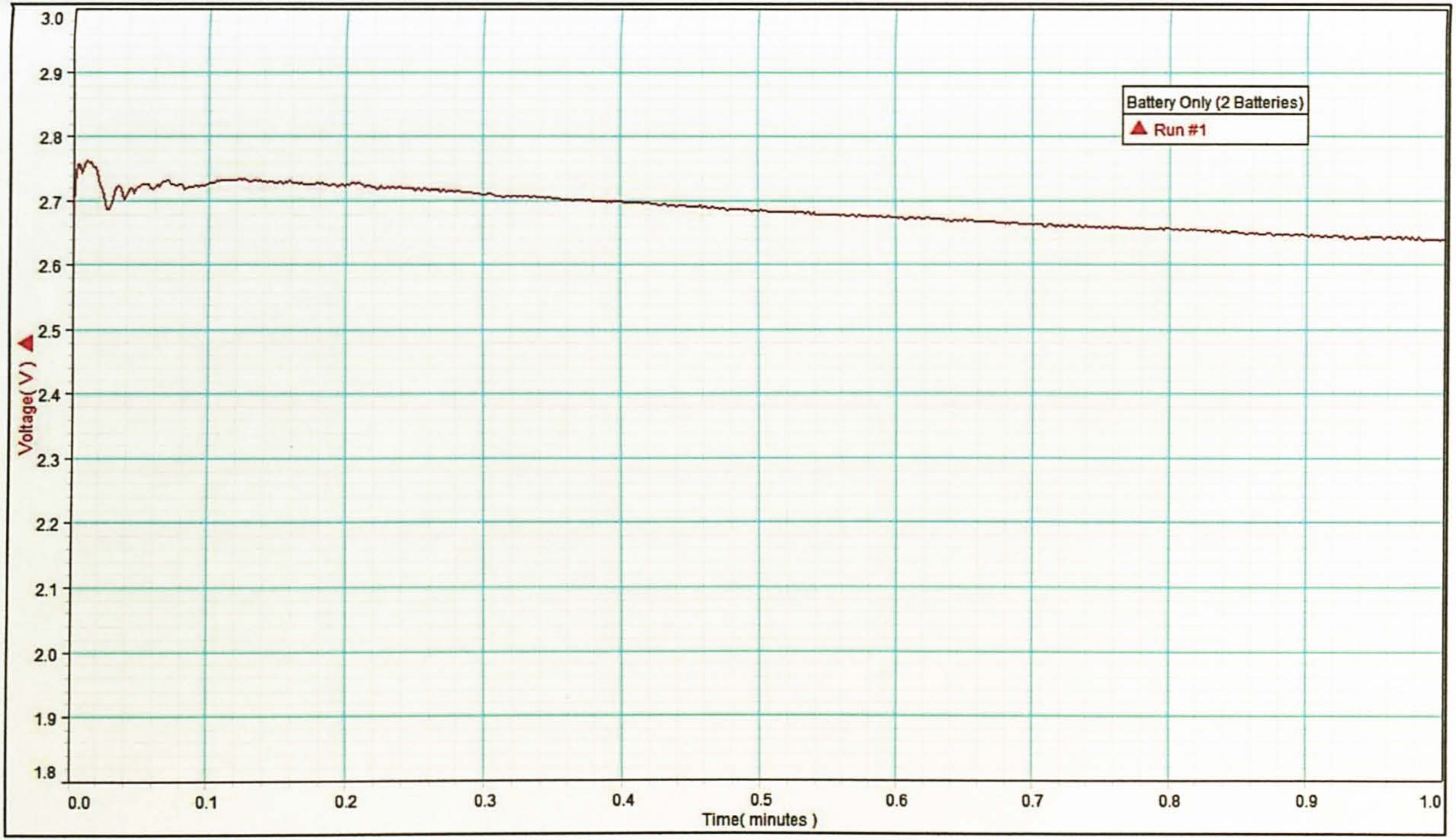
Appendix C.4: Full page view of the voltage waveform across the light bulb for parallel connection between ultracapacitor (1500 miliFarad) and battery for the first one minute for one manganese battery



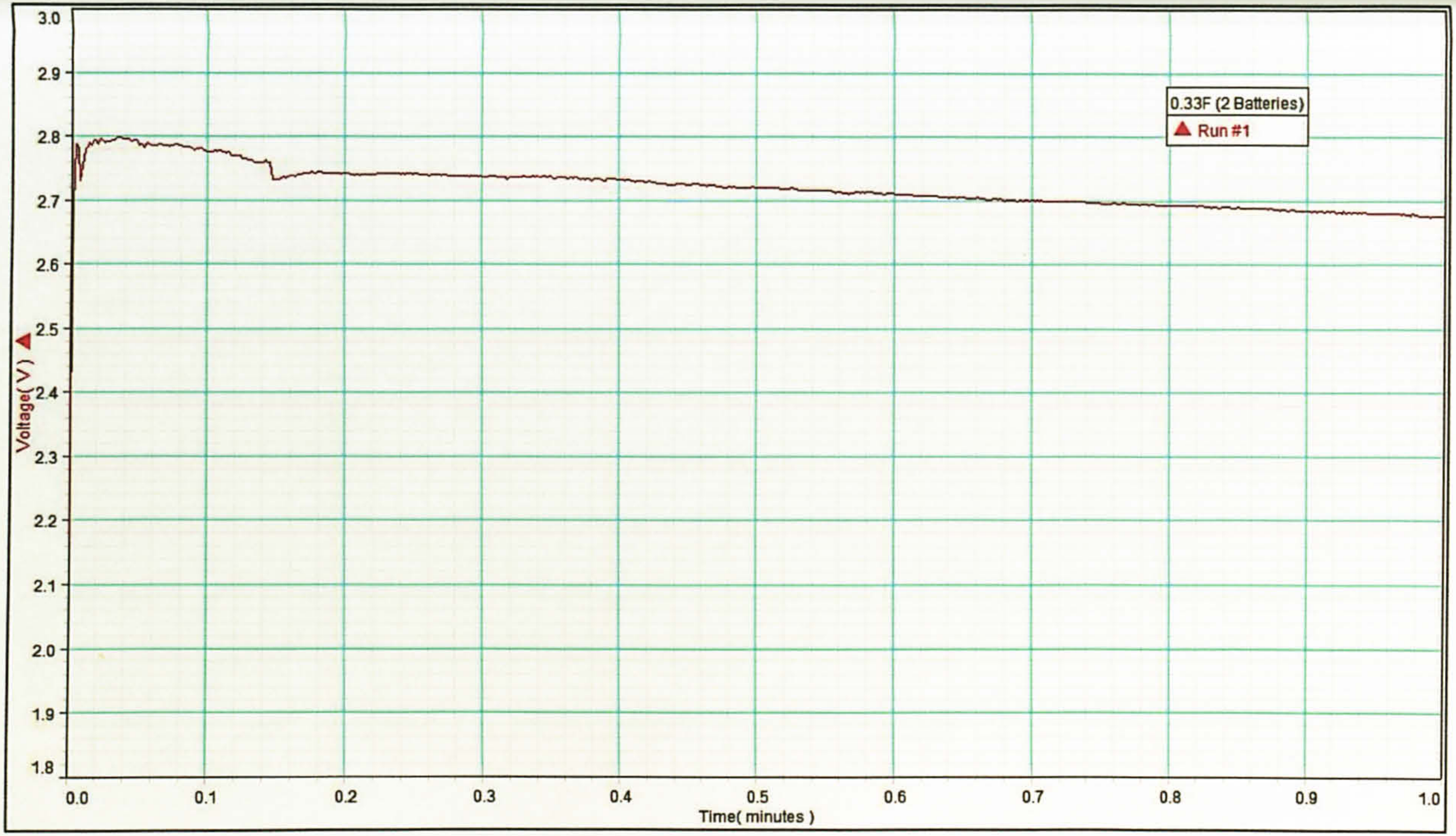
Appendix C.5: Full page view of the voltage waveform across the light bulb for parallel connection between ultracapacitor (22000 miliFarad) and battery for the first one minute for one manganese battery

APPENDIX D

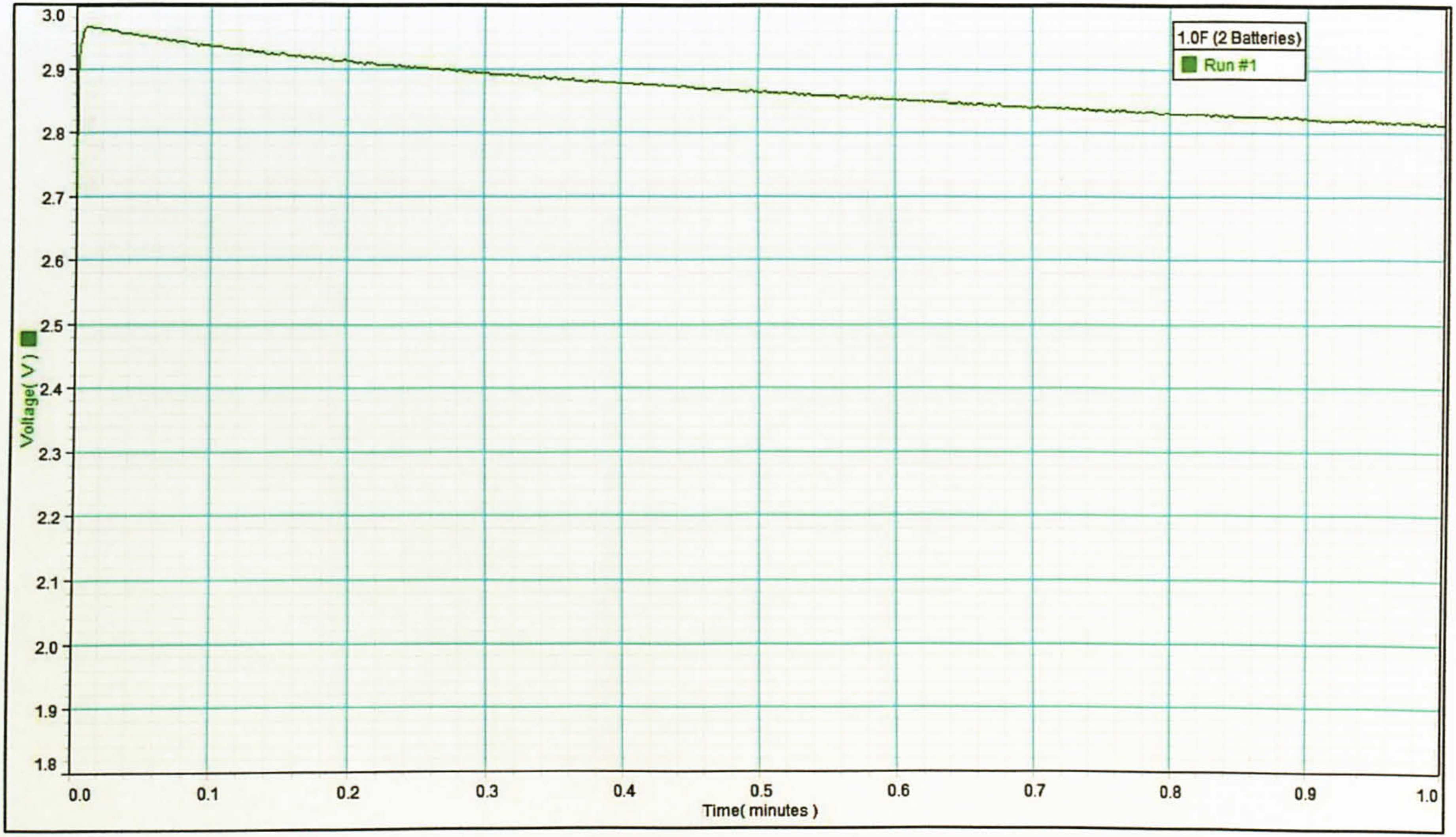
VOLTAGE WAVEFORMS FOR TWO MANGANESE BATTERIES CIRCUIT ARRANGEMENT FOR THE INSTANTANEOUS POWER OR PEAK POWER PROVIDED TO DEVICES



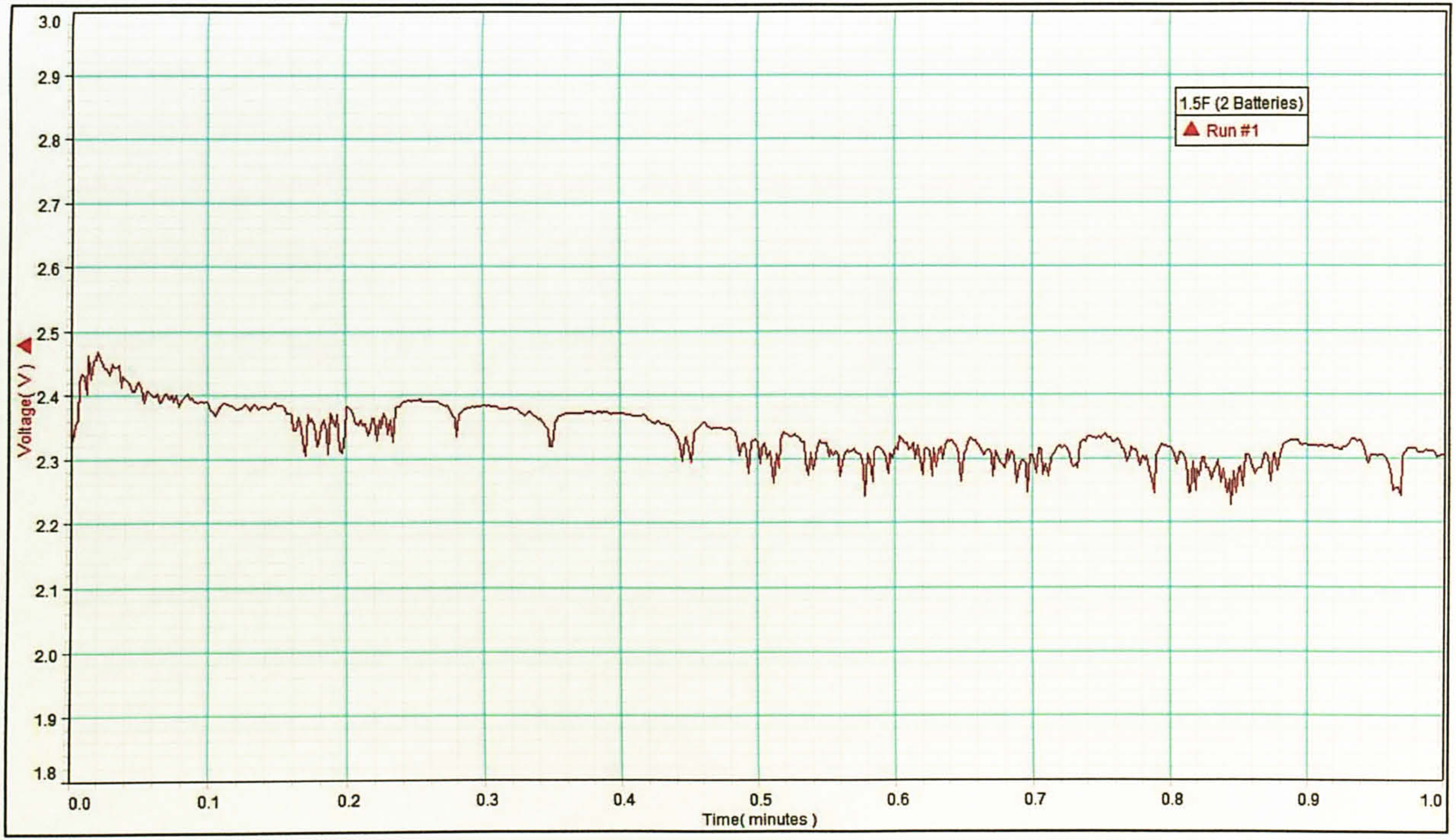
Appendix D.1: Full page view of the voltage waveform across the light bulb for stand-alone battery circuit arrangement for the first one minute for two manganese batteries



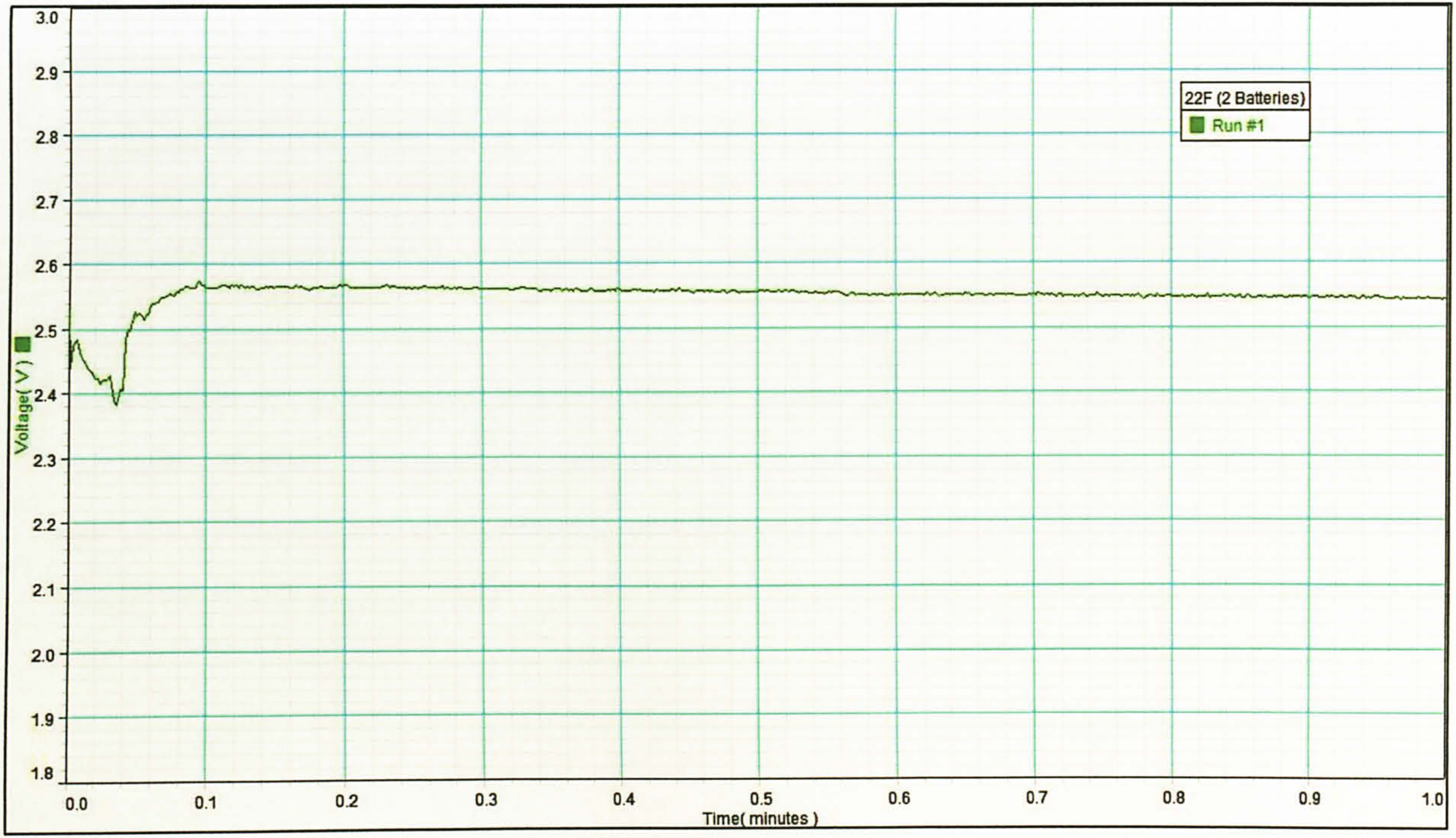
Appendix D.2: Full page view of the voltage waveform across the light bulb for parallel connection between ultracapacitor (330 miliFarad) and battery for the first one minute for two manganese batteries



Appendix D.3: Full page view of the voltage waveform across the light bulb for parallel connection between ultracapacitor (1000 miliFarad) and battery for the first one minute for two manganese batteries



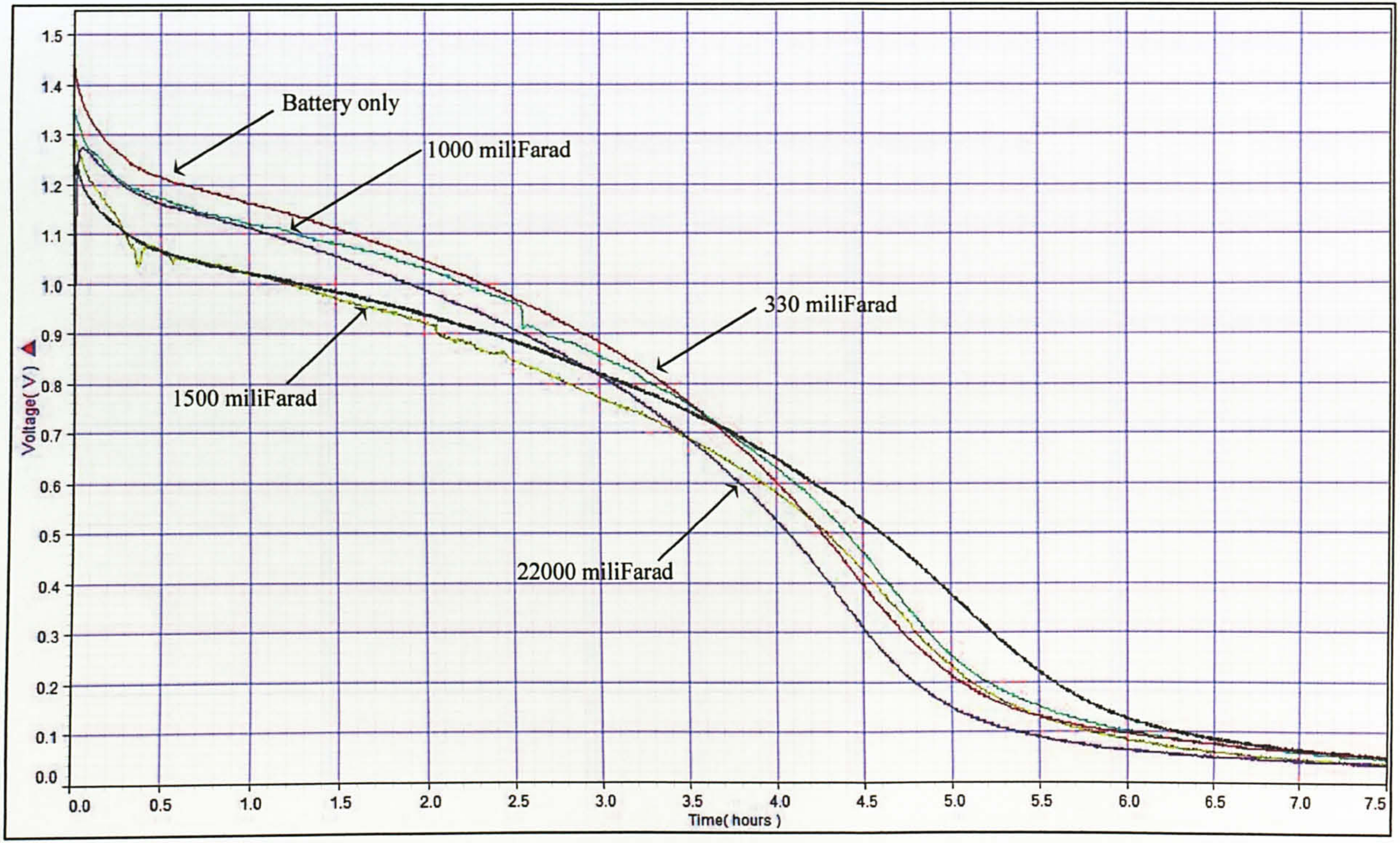
Appendix D.4: Full page view of the voltage waveform across the light bulb for parallel connection between ultracapacitor (1500 miliFarad) and battery for the first one minute for two manganese batteries



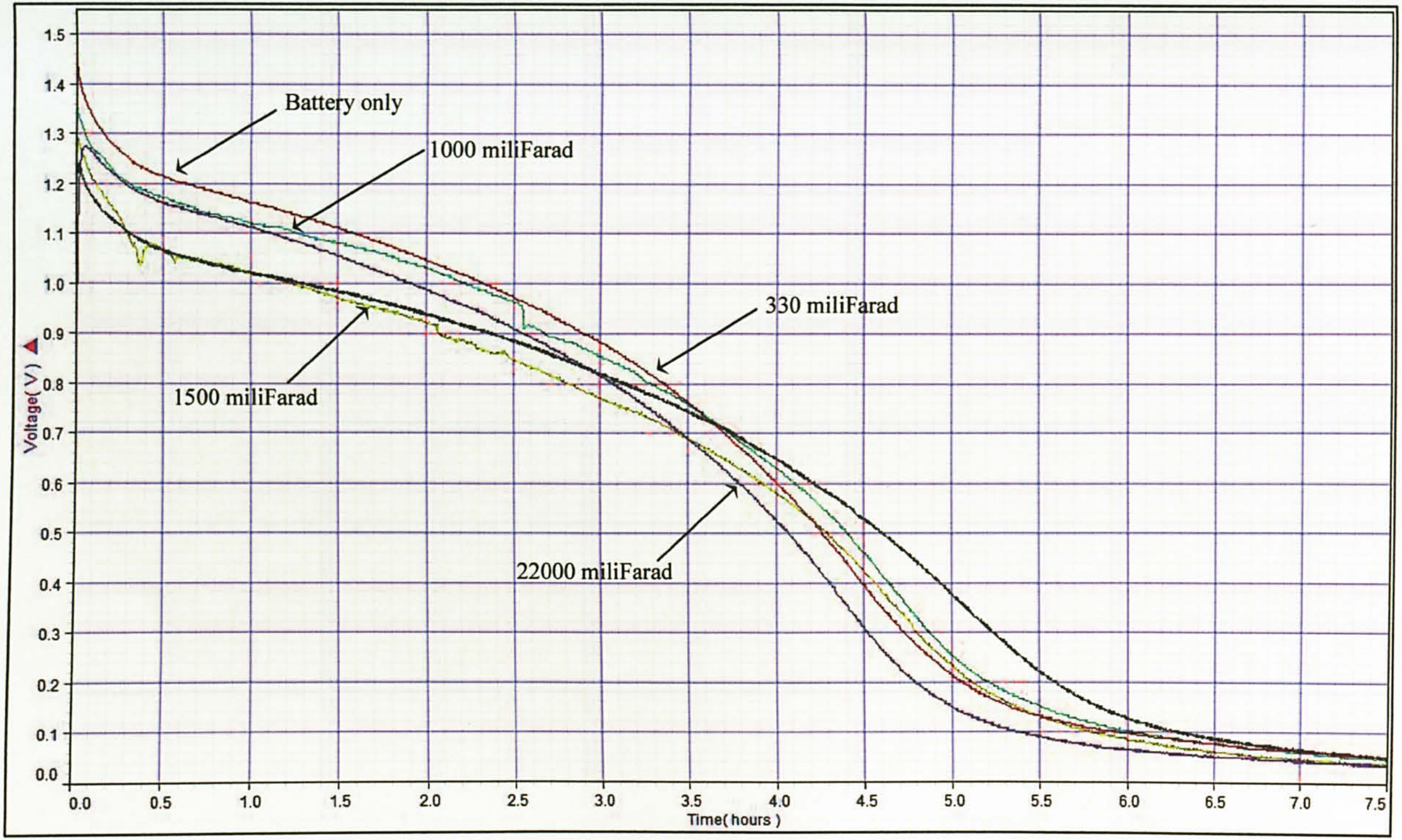
Appendix D.5: Full page view of the voltage waveform across the light bulb for parallel connection between ultracapacitor (22000 miliFarad) and battery for the first one minute for two manganese batteries

APPENDIX E

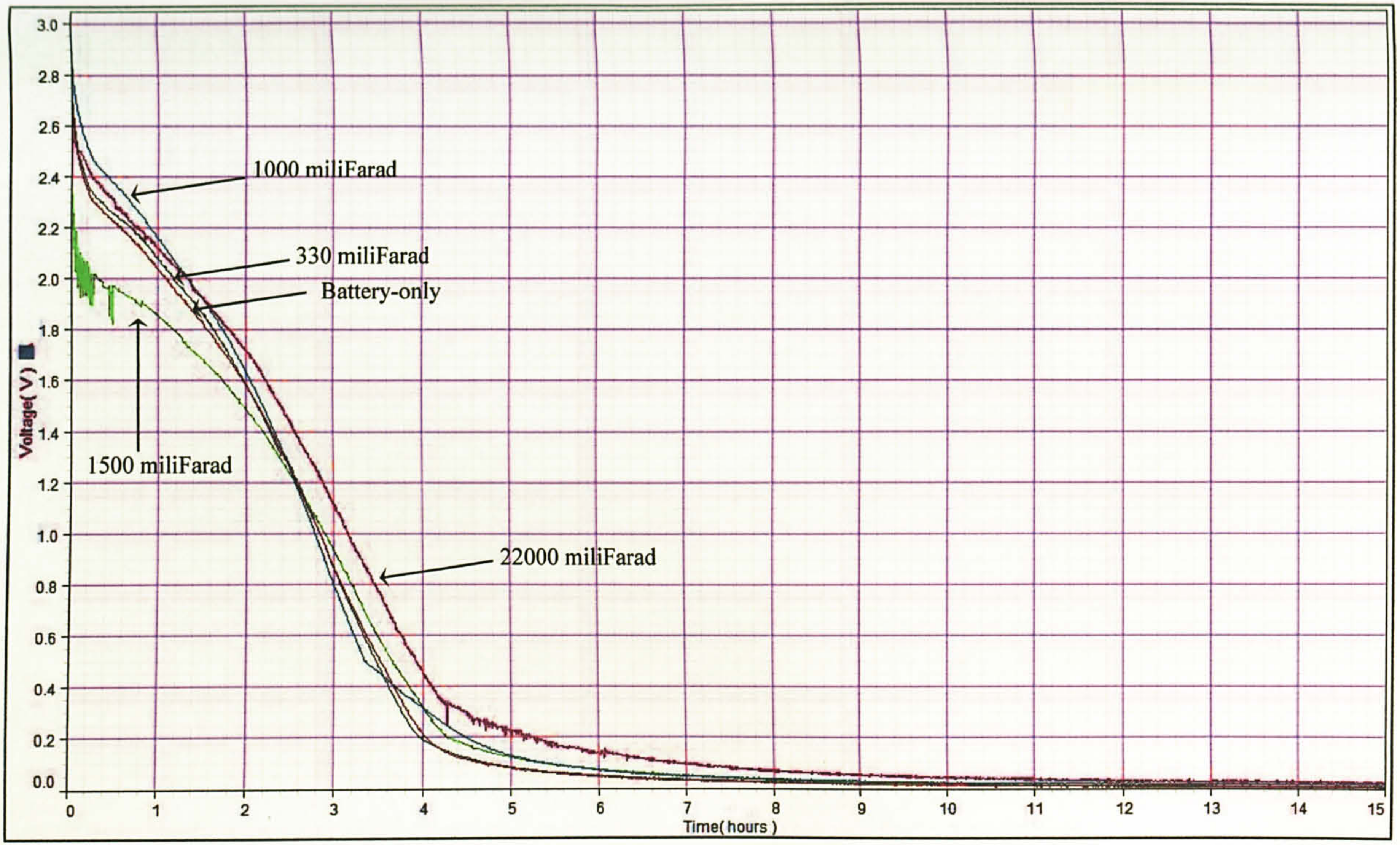
EVERY VOLTAGE WAVEFORMS FOR BOTH ONE MANGANESE BATTERY AND TWO MANGANESE BATTERIES CIRCUIT ARRANGEMENT FOR THE RUNTIME OF THE DEVICES



Appendix E.1: Full page view for the comparison of every waveform for the voltage across the load for one manganese battery



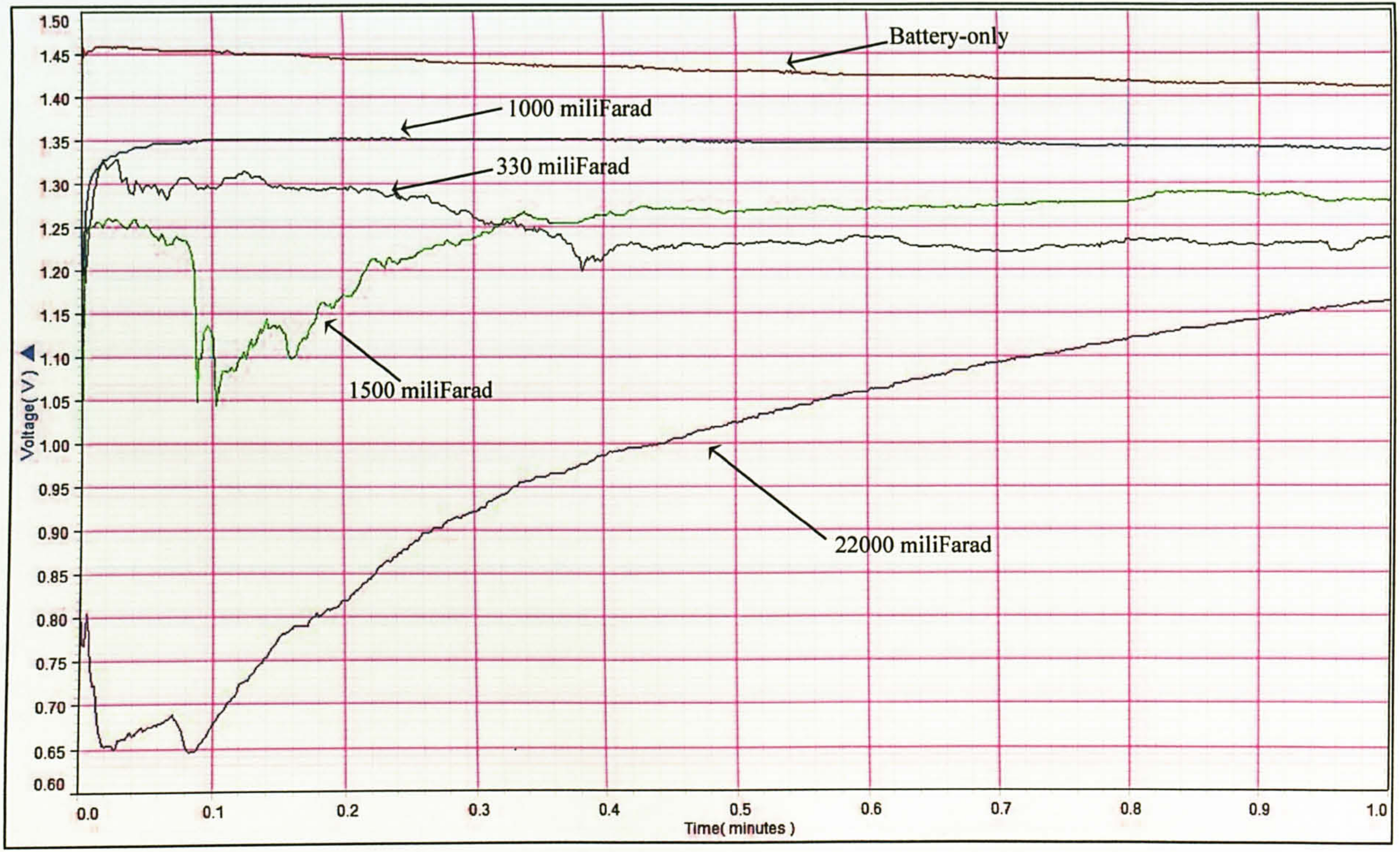
Appendix E.1: Full page view for the comparison of every waveform for the voltage across the load for one manganese battery



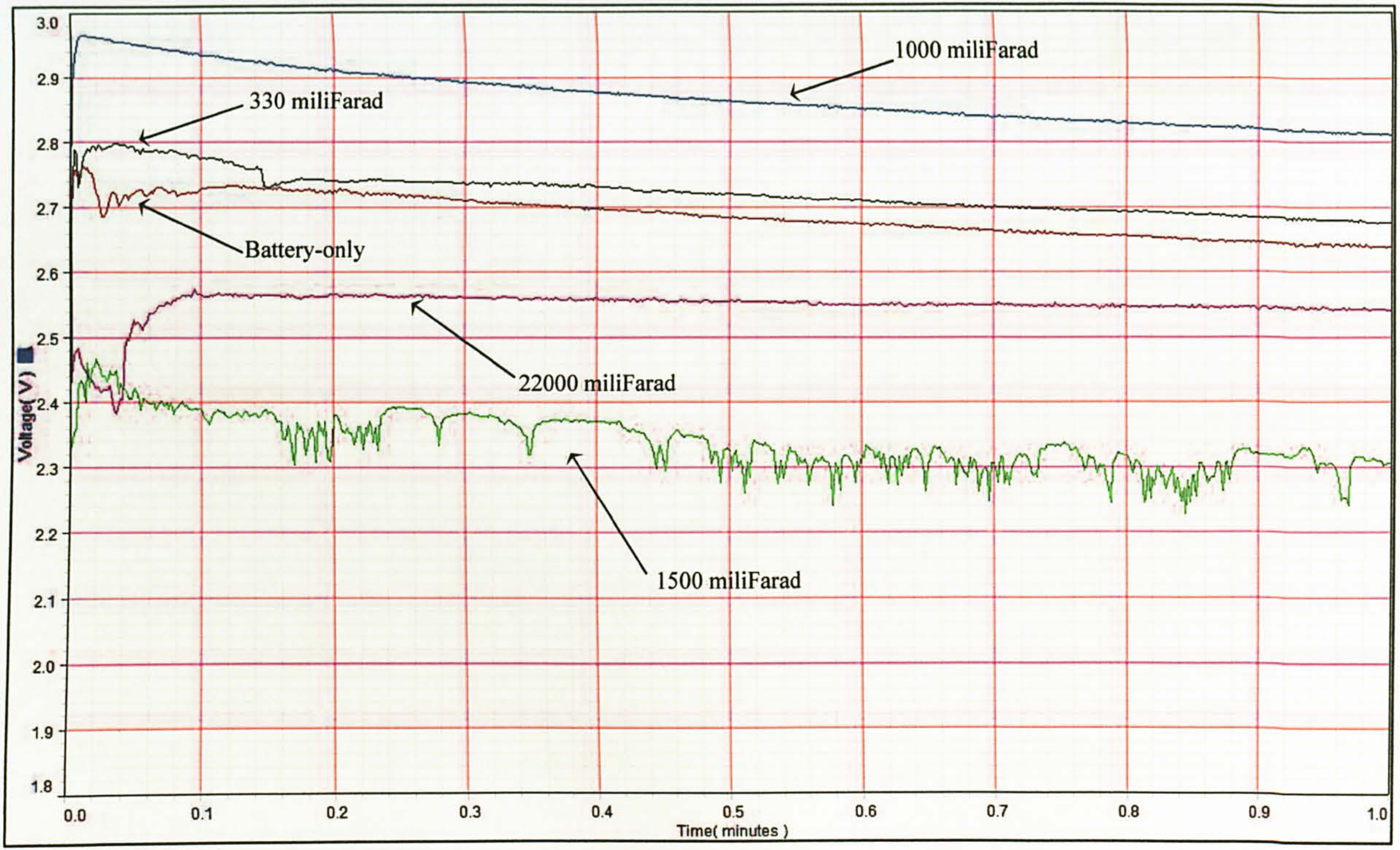
Appendix E.2: Full page view for the comparison of every waveform for the voltage across the load for two manganese batteries

APPENDIX F

EVERY VOLTAGE WAVEFORMS FOR BOTH ONE MANGANESE BATTERY AND TWO MANGANESE BATTERIES CIRCUIT ARRANGEMENT FOR THE INSTANTANEOUS POWER OR PEAK POWER PROVIDED TO THE DEVICES



Appendix F.1: Full page view for the comparison of every waveform for the first one minute in voltage that across the load for one manganese battery



Appendix F.2: Full page view for the comparison of every waveform for the first one minute in voltage that across the load for two manganese batteries

APPENDIX G

THE DATA SHEETS OF THE VOLTAGE ACROSS THE LOAD FOR THE FIRST ONE MINUTE FOR ONE MANGANESE BATTERY CIRCUIT ARRANGEMENT

APPENDIX G.1

BATTERY-ONLY CIRCUIT ARRANGEMENT FOR ONE MANGANESE BATTERY CIRCUIT ARRANGEMENT

Time (s)	Voltage (V)	Time (s)	Voltage (V)	Time (s)	Voltage (V)	Time (s)	Voltage (V)	Time (s)	Voltage (V)	Time (s)	Voltage (V)
0	1.4356	8.1	1.4502	16.2	1.4417	24.3	1.4356	32.4	1.4289	40.5	1.4234
0.1	1.4588	8.2	1.4502	16.3	1.4423	24.4	1.4356	32.5	1.4295	40.6	1.4234
0.2	1.4502	8.3	1.4502	16.4	1.4417	24.5	1.4356	32.6	1.4277	40.7	1.424
0.3	1.4551	8.4	1.4502	16.5	1.4417	24.6	1.4356	32.7	1.4289	40.8	1.4246
0.4	1.4551	8.5	1.4502	16.6	1.4411	24.7	1.4356	32.8	1.4283	40.9	1.424
0.5	1.4551	8.6	1.4502	16.7	1.4405	24.8	1.435	32.9	1.4283	41	1.4234
0.6	1.4582	8.7	1.4502	16.8	1.4417	24.9	1.4356	33	1.4277	41.1	1.4228
0.7	1.4594	8.8	1.4502	16.9	1.4423	25	1.4356	33.1	1.427	41.2	1.4228
0.8	1.46	8.9	1.4502	17	1.4411	25.1	1.435	33.2	1.427	41.3	1.424
0.9	1.4594	9	1.4502	17.1	1.4405	25.2	1.435	33.3	1.4277	41.4	1.4228
1	1.4594	9.1	1.4502	17.2	1.4417	25.3	1.435	33.4	1.427	41.5	1.4222
1.1	1.4594	9.2	1.4502	17.3	1.4411	25.4	1.435	33.5	1.4283	41.6	1.4216
1.2	1.4594	9.3	1.4502	17.4	1.4405	25.5	1.4356	33.6	1.4283	41.7	1.4222
1.3	1.4594	9.4	1.4502	17.5	1.4405	25.6	1.4356	33.7	1.4277	41.8	1.4216
1.4	1.4588	9.5	1.4502	17.6	1.4405	25.7	1.4356	33.8	1.4277	41.9	1.4209
1.5	1.4594	9.6	1.4502	17.7	1.4399	25.8	1.4338	33.9	1.427	42	1.4216
1.6	1.4588	9.7	1.4502	17.8	1.4405	25.9	1.435	34	1.427	42.1	1.4216
1.7	1.46	9.8	1.4496	17.9	1.4399	26	1.4344	34.1	1.427	42.2	1.4216
1.8	1.4594	9.9	1.4502	18	1.4405	26.1	1.4344	34.2	1.4258	42.3	1.4216
1.9	1.46	10	1.4502	18.1	1.4399	26.2	1.4344	34.3	1.4264	42.4	1.4209
2	1.4594	10.1	1.449	18.2	1.4405	26.3	1.4338	34.4	1.4264	42.5	1.4209
2.1	1.46	10.2	1.4496	18.3	1.4405	26.4	1.4325	34.5	1.4258	42.6	1.4209
2.2	1.4582	10.3	1.4496	18.4	1.4399	26.5	1.4325	34.6	1.4264	42.7	1.4209
2.3	1.4588	10.4	1.4496	18.5	1.4399	26.6	1.4325	34.7	1.4264	42.8	1.4216
2.4	1.4576	10.5	1.4484	18.6	1.4399	26.7	1.4338	34.8	1.427	42.9	1.4209
2.5	1.4576	10.6	1.4478	18.7	1.4399	26.8	1.4325	34.9	1.4264	43	1.4209
2.6	1.4576	10.7	1.4484	18.8	1.4393	26.9	1.4325	35	1.4264	43.1	1.4209
2.7	1.4576	10.8	1.4472	18.9	1.4405	27	1.4319	35.1	1.4258	43.2	1.4209
2.8	1.457	10.9	1.4478	19	1.4393	27.1	1.4331	35.2	1.4264	43.3	1.4209
2.9	1.457	11	1.4478	19.1	1.4393	27.2	1.4313	35.3	1.4258	43.4	1.4209
3	1.4563	11.1	1.4484	19.2	1.4399	27.3	1.4307	35.4	1.4264	43.5	1.4209
3.1	1.4563	11.2	1.4472	19.3	1.4399	27.4	1.4331	35.5	1.4264	43.6	1.4209
3.2	1.457	11.3	1.4472	19.4	1.4386	27.5	1.4319	35.6	1.4264	43.7	1.4209
3.3	1.4563	11.4	1.4454	19.5	1.4386	27.6	1.4307	35.7	1.4258	43.8	1.4209
3.4	1.4563	11.5	1.4466	19.6	1.4386	27.7	1.4307	35.8	1.4264	43.9	1.4209
3.5	1.4563	11.6	1.4466	19.7	1.4393	27.8	1.4307	35.9	1.4264	44	1.4209
3.6	1.4557	11.7	1.4466	19.8	1.4374	27.9	1.4307	36	1.4258	44.1	1.4209
3.7	1.4557	11.8	1.446	19.9	1.4386	28	1.4307	36.1	1.4258	44.2	1.4209
3.8	1.4551	11.9	1.4454	20	1.438	28.1	1.4307	36.2	1.4258	44.3	1.4209
3.9	1.4551	12	1.4466	20.1	1.4374	28.2	1.4307	36.3	1.4264	44.4	1.4209
4	1.4557	12.1	1.4454	20.2	1.4386	28.3	1.4313	36.4	1.4258	44.5	1.4209
4.1	1.4551	12.2	1.4454	20.3	1.4386	28.4	1.4307	36.5	1.4258	44.6	1.4209
4.2	1.4551	12.3	1.4454	20.4	1.4374	28.5	1.4307	36.6	1.4258	44.7	1.4209
4.3	1.4545	12.4	1.4454	20.5	1.438	28.6	1.4307	36.7	1.4258	44.8	1.4209
4.4	1.4551	12.5	1.4454	20.6	1.4374	28.7	1.4313	36.8	1.4258	44.9	1.4209
4.5	1.4551	12.6	1.4454	20.7	1.4362	28.8	1.4307	36.9	1.4258	45	1.4209
4.6	1.4551	12.7	1.4454	20.8	1.4386	28.9	1.4307	37	1.4258	45.1	1.4209
4.7	1.4551	12.8	1.4454	20.9	1.4362	29	1.4307	37.1	1.4258	45.2	1.4209
4.8	1.4551	12.9	1.4454	21	1.438	29.1	1.4307	37.2	1.4258	45.3	1.4209
4.9	1.4551	13	1.4454	21.1	1.438	29.2	1.4307	37.3	1.4258	45.4	1.4209
5	1.4551	13.1	1.4454	21.2	1.4362	29.3	1.4307	37.4	1.4258	45.5	1.4209
5.1	1.4551	13.2	1.4454	21.3	1.4362	29.4	1.4307	37.5	1.4258	45.6	1.4209
5.2	1.4551	13.3	1.4454	21.4	1.4356	29.5	1.4307	37.6	1.4252	45.7	1.4209
5.3	1.4551	13.4	1.4454	21.5	1.4368	29.6	1.4307	37.7	1.4258	45.8	1.4209
5.4	1.4551	13.5	1.4454	21.6	1.4362	29.7	1.4307	37.8	1.4258	45.9	1.4209
5.5	1.4551	13.6	1.4454	21.7	1.4362	29.8	1.4307	37.9	1.4252	46	1.4216
5.6	1.4551	13.7	1.4454	21.8	1.4356	29.9	1.4307	38	1.4258	46.1	1.4209
5.7	1.4545	13.8	1.4454	21.9	1.4362	30	1.4307	38.1	1.4252	46.2	1.4209
5.8	1.4551	13.9	1.4454	22	1.4356	30.1	1.4307	38.2	1.4252	46.3	1.4209
5.9	1.4551	14	1.4454	22.1	1.4362	30.2	1.4301	38.3	1.4252	46.4	1.4209
6	1.4545	14.1	1.4454	22.2	1.4356	30.3	1.4307	38.4	1.4258	46.5	1.4197
6.1	1.4551	14.2	1.4454	22.3	1.4356	30.4	1.4307	38.5	1.4258	46.6	1.4203
6.2	1.4539	14.3	1.4454	22.4	1.4356	30.5	1.4307	38.6	1.4258	46.7	1.4203
6.3	1.4539	14.4	1.4454	22.5	1.4356	30.6	1.4313	38.7	1.4258	46.8	1.4197
6.4	1.4527	14.5	1.4454	22.6	1.4356	30.7	1.4307	38.8	1.4252	46.9	1.4185
6.5	1.4527	14.6	1.4447	22.7	1.4356	30.8	1.4307	38.9	1.4252	47	1.4203
6.6	1.4533	14.7	1.4441	22.8	1.4356	30.9	1.4301	39	1.424	47.1	1.4203
6.7	1.4545	14.8	1.4447	22.9	1.4356	31	1.4301	39.1	1.4252	47.2	1.4191
6.8	1.4533	14.9	1.4447	23	1.4356	31.1	1.4307	39.2	1.4246	47.3	1.4185
6.9	1.4527	15	1.4441	23.1	1.4356	31.2	1.4307	39.3	1.4252	47.4	1.4185
7	1.4515	15.1	1.4441	23.2	1.4356	31.3	1.4301	39.4	1.4252	47.5	1.4197
7.1	1.4508	15.2	1.4454	23.3	1.4356	31.4	1.4301	39.5	1.4252	47.6	1.4185
7.2	1.4508	15.3	1.4435	23.4	1.4356	31.5	1.4307	39.6	1.4252	47.7	1.4185
7.3	1.4508	15.4	1.4435	23.5	1.4356	31.6	1.4307	39.7	1.4246	47.8	1.4179
7.4	1.4508	15.5	1.4435	23.6	1.4356	31.7	1.4295	39.8	1.4246	47.9	1.4191
7.5	1.4527	15.6	1.4435	23.7	1.4356	31.8	1.4307	39.9	1.4252	48	1.4197
7.6	1.4502	15.7	1.4441	23.8	1.4356	31.9	1.4295	40	1.4246	48.1	1.4179
7.7	1.4508	15.8	1.4435	23.9	1.4356	32	1.4289	40.1	1.4246	48.2	1.4185
7.8	1.4508	15.9	1.4423	24	1.4356	32.1	1.4289	40.2	1.424	48.3	1.4185
7.9	1.4502	16	1.4417	24.1	1.4356	32.2	1.4277	40.3	1.4246	48.4	1.4185
8	1.4502	16.1	1.4417	24.2	1.4356	32.3	1.4301	40.4	1.4246	48.5	1.4185

Time (s)	Voltage (V)
48.6	1.4185
48.7	1.4179
48.8	1.4185
48.9	1.4179
49	1.4173
49.1	1.4173
49.2	1.4161
49.3	1.4167
49.4	1.4167
49.5	1.4161
49.6	1.4173
49.7	1.4161
49.8	1.4167
49.9	1.4167
50	1.4161
50.1	1.4173
50.2	1.4161
50.3	1.4161
50.4	1.4167
50.5	1.4161
50.6	1.4161
50.7	1.4167
50.8	1.4161
50.9	1.4161
51	1.4167
51.1	1.4161
51.2	1.4161
51.3	1.4161
51.4	1.4161
51.5	1.4161
51.6	1.4161
51.7	1.4161
51.8	1.4161
51.9	1.4161
52	1.4161
52.1	1.4161
52.2	1.4167
52.3	1.4167
52.4	1.4161
52.5	1.4161
52.6	1.4161
52.7	1.4161
52.8	1.4161
52.9	1.4161
53	1.4161
53.1	1.4161
53.2	1.4161
53.3	1.4161
53.4	1.4161
53.5	1.4161
53.6	1.4161
53.7	1.4161
53.8	1.4161
53.9	1.4161
54	1.4154
54.1	1.4161
54.2	1.4161
54.3	1.4161
54.4	1.4161
54.5	1.4161
54.6	1.4148
54.7	1.4161
54.8	1.4154
54.9	1.4154
55	1.4161
55.1	1.4161
55.2	1.4161
55.3	1.4161
55.4	1.4148
55.5	1.4148
55.6	1.4161
55.7	1.4154
55.8	1.4142
55.9	1.4148
56	1.4142
56.1	1.4148
56.2	1.4136
56.3	1.4154
56.4	1.4154
56.5	1.4148
56.6	1.4142
56.7	1.4142

Time (s)	Voltage (V)
56.8	1.4142
56.9	1.4154
57	1.4142
57.1	1.4142
57.2	1.4142
57.3	1.4142
57.4	1.4136
57.5	1.4136
57.6	1.4124
57.7	1.413
57.8	1.4124
57.9	1.4136
58	1.4124
58.1	1.4136
58.2	1.4136
58.3	1.413
58.4	1.413
58.5	1.413
58.6	1.413
58.7	1.413
58.8	1.4124
58.9	1.4124
59	1.4124
59.1	1.4118
59.2	1.4118
59.3	1.4124
59.4	1.4112
59.5	1.4118
59.6	1.4118
59.7	1.4112
59.8	1.4118
59.9	1.4118
60	1.4118

APPENDIX G.2

PARALLEL CONNECTION BETWEEN 330 MILIFARAD CAPACITANCE OF ULTRACAPACITOR WITH ONE MANGANESE BATTERY

Time (s)	Voltage (V)	Time (s)	Voltage (V)	Time (s)	Voltage (V)	Time (s)	Voltage (V)	Time (s)	Voltage (V)	Time (s)	Voltage (V)
0	1.0779	8.1	1.3092	16.2	1.2787	24.3	1.2244	32.4	1.2329	40.5	1.2232
0.1	1.1487	8.2	1.3092	16.3	1.2787	24.4	1.2232	32.5	1.2323	40.6	1.2238
0.2	1.1988	8.3	1.3068	16.4	1.2775	24.5	1.2275	32.6	1.2323	40.7	1.2226
0.3	1.225	8.4	1.305	16.5	1.2763	24.6	1.2299	32.7	1.2323	40.8	1.2232
0.4	1.2488	8.5	1.3007	16.6	1.2757	24.7	1.2281	32.8	1.2317	40.9	1.2232
0.5	1.2641	8.6	1.2989	16.7	1.2745	24.8	1.2305	32.9	1.2317	41	1.222
0.6	1.294	8.7	1.2983	16.8	1.2726	24.9	1.2305	33	1.2305	41.1	1.2214
0.7	1.3007	8.8	1.2964	16.9	1.2696	25	1.2293	33.1	1.2299	41.2	1.2207
0.8	1.3153	8.9	1.2976	17	1.2683	25.1	1.2299	33.2	1.2281	41.3	1.2232
0.9	1.3202	9	1.297	17.1	1.269	25.2	1.2336	33.3	1.2299	41.4	1.2232
1	1.3282	9.1	1.2995	17.2	1.2659	25.3	1.2317	33.4	1.2305	41.5	1.2226
1.1	1.3251	9.2	1.2976	17.3	1.2659	25.4	1.2299	33.5	1.2317	41.6	1.2226
1.2	1.319	9.3	1.297	17.4	1.2696	25.5	1.2323	33.6	1.2317	41.7	1.2226
1.3	1.3215	9.4	1.2952	17.5	1.2702	25.6	1.2317	33.7	1.2329	41.8	1.2214
1.4	1.3239	9.5	1.2958	17.6	1.2696	25.7	1.2275	33.8	1.2336	41.9	1.222
1.5	1.3263	9.6	1.2952	17.7	1.2677	25.8	1.2268	33.9	1.2342	42	1.2226
1.6	1.3288	9.7	1.2964	17.8	1.2671	25.9	1.2268	34	1.2336	42.1	1.222
1.7	1.3282	9.8	1.2952	17.9	1.2653	26	1.2256	34.1	1.2336	42.2	1.222
1.8	1.3202	9.9	1.2946	18	1.2604	26.1	1.2256	34.2	1.2323	42.3	1.222
1.9	1.3044	10	1.294	18.1	1.2604	26.2	1.2226	34.3	1.2317	42.4	1.222
2	1.3062	10.1	1.2958	18.2	1.2586	26.3	1.2256	34.4	1.2317	42.5	1.222
2.1	1.3074	10.2	1.2958	18.3	1.2586	26.4	1.2238	34.5	1.2323	42.6	1.222
2.2	1.2946	10.3	1.2952	18.4	1.2574	26.5	1.2275	34.6	1.2342	42.7	1.222
2.3	1.2897	10.4	1.2952	18.5	1.2531	26.6	1.2275	34.7	1.2342	42.8	1.2226
2.4	1.2891	10.5	1.2934	18.6	1.2549	26.7	1.2293	34.8	1.2348	42.9	1.2226
2.5	1.305	10.6	1.2946	18.7	1.2537	26.8	1.2262	34.9	1.2329	43	1.222
2.6	1.3019	10.7	1.2928	18.8	1.2561	26.9	1.2275	35	1.2354	43.1	1.2207
2.7	1.2995	10.8	1.2934	18.9	1.2531	27	1.2275	35.1	1.236	43.2	1.2207
2.8	1.2922	10.9	1.2928	19	1.2537	27.1	1.2305	35.2	1.2384	43.3	1.222
2.9	1.2964	11	1.294	19.1	1.2543	27.2	1.2262	35.3	1.2384	43.4	1.2226
3	1.2989	11.1	1.2946	19.2	1.2537	27.3	1.2262	35.4	1.2391	43.5	1.2232
3.1	1.2989	11.2	1.2934	19.3	1.2537	27.4	1.2293	35.5	1.2403	43.6	1.2226
3.2	1.297	11.3	1.2952	19.4	1.2531	27.5	1.2293	35.6	1.2409	43.7	1.2232
3.3	1.2976	11.4	1.2964	19.5	1.2561	27.6	1.2317	35.7	1.2391	43.8	1.2238
3.4	1.3001	11.5	1.2958	19.6	1.2555	27.7	1.2311	35.8	1.2397	43.9	1.2238
3.5	1.2946	11.6	1.297	19.7	1.2555	27.8	1.2317	35.9	1.2391	44	1.2262
3.6	1.2891	11.7	1.2952	19.8	1.2574	27.9	1.2311	36	1.2384	44.1	1.2275
3.7	1.2946	11.8	1.2952	19.9	1.2568	28	1.2305	36.1	1.2384	44.2	1.2281
3.8	1.2909	11.9	1.2952	20	1.2513	28.1	1.2293	36.2	1.2372	44.3	1.2293
3.9	1.2836	12	1.2946	20.1	1.2525	28.2	1.2299	36.3	1.2378	44.4	1.2293
4	1.2848	12.1	1.2958	20.2	1.2531	28.3	1.2305	36.4	1.2384	44.5	1.2293
4.1	1.2952	12.2	1.294	20.3	1.2513	28.4	1.2305	36.5	1.2391	44.6	1.2287
4.2	1.297	12.3	1.2976	20.4	1.247	28.5	1.2299	36.6	1.2391	44.7	1.2275
4.3	1.2995	12.4	1.2958	20.5	1.2476	28.6	1.2275	36.7	1.2378	44.8	1.2275
4.4	1.3001	12.5	1.2952	20.6	1.2476	28.7	1.2275	36.8	1.2372	44.9	1.2262
4.5	1.3062	12.6	1.2934	20.7	1.2464	28.8	1.2268	36.9	1.2384	45	1.2256
4.6	1.3086	12.7	1.2909	20.8	1.25	28.9	1.2256	37	1.2391	45.1	1.2256
4.7	1.3086	12.8	1.2928	20.9	1.2452	29	1.2256	37.1	1.2391	45.2	1.2275
4.8	1.3086	12.9	1.294	21	1.2494	29.1	1.2268	37.2	1.2397	45.3	1.2281
4.9	1.3074	13	1.2952	21.1	1.2482	29.2	1.2268	37.3	1.2378	45.4	1.2293
5	1.3062	13.1	1.294	21.2	1.247	29.3	1.2287	37.4	1.2372	45.5	1.2287
5.1	1.3044	13.2	1.2946	21.3	1.2445	29.4	1.2305	37.5	1.2366	45.6	1.2281
5.2	1.3001	13.3	1.2928	21.4	1.2427	29.5	1.2311	37.6	1.2329	45.7	1.2275
5.3	1.297	13.4	1.2934	21.5	1.2403	29.6	1.2311	37.7	1.2323	45.8	1.2293
5.4	1.2946	13.5	1.2928	21.6	1.2384	29.7	1.2317	37.8	1.2323	45.9	1.2287
5.5	1.2958	13.6	1.2915	21.7	1.2397	29.8	1.2317	37.9	1.2299	46	1.2287
5.6	1.2952	13.7	1.2903	21.8	1.2403	29.9	1.2317	38	1.2287	46.1	1.2268
5.7	1.297	13.8	1.2885	21.9	1.2421	30	1.2323	38.1	1.2287	46.2	1.2275
5.8	1.2989	13.9	1.286	22	1.2421	30.1	1.2305	38.2	1.2281	46.3	1.2287
5.9	1.2964	14	1.2854	22.1	1.236	30.2	1.2311	38.3	1.2281	46.4	1.2268
6	1.2958	14.1	1.2867	22.2	1.2354	30.3	1.2305	38.4	1.2268	46.5	1.2268
6.1	1.2964	14.2	1.2879	22.3	1.2323	30.4	1.2293	38.5	1.2275	46.6	1.2299
6.2	1.2952	14.3	1.2879	22.4	1.2311	30.5	1.2311	38.6	1.2275	46.7	1.2262
6.3	1.2983	14.4	1.2885	22.5	1.2305	30.6	1.2311	38.7	1.2275	46.8	1.2311
6.4	1.2995	14.5	1.2848	22.6	1.2238	30.7	1.2311	38.8	1.2268	46.9	1.2287
6.5	1.3031	14.6	1.2836	22.7	1.2165	30.8	1.2311	38.9	1.2268	47	1.2305
6.6	1.3086	14.7	1.286	22.8	1.2152	30.9	1.2311	39	1.2275	47.1	1.2323
6.7	1.3086	14.8	1.2836	22.9	1.2159	31	1.2329	39.1	1.2281	47.2	1.2329
6.8	1.3074	14.9	1.2818	23	1.1988	31.1	1.2317	39.2	1.2268	47.3	1.2323
6.9	1.3086	15	1.2836	23.1	1.2079	31.2	1.2336	39.3	1.2275	47.4	1.2329
7	1.3086	15.1	1.286	23.2	1.2152	31.3	1.2329	39.4	1.2281	47.5	1.2311
7.1	1.3086	15.2	1.2854	23.3	1.2122	31.4	1.2329	39.5	1.2275	47.6	1.2317
7.2	1.3105	15.3	1.286	23.4	1.2159	31.5	1.2336	39.6	1.2293	47.7	1.2317
7.3	1.3123	15.4	1.2848	23.5	1.2165	31.6	1.2342	39.7	1.2293	47.8	1.2323
7.4	1.3123	15.5	1.286	23.6	1.211	31.7	1.2329	39.8	1.2287	47.9	1.236
7.5	1.3147	15.6	1.2867	23.7	1.214	31.8	1.2329	39.9	1.2281	48	1.236
7.6	1.3141	15.7	1.2848	23.8	1.211	31.9	1.2329	40	1.2262	48.1	1.2348
7.7	1.3123	15.8	1.2879	23.9	1.2128	32	1.2329	40.1	1.2268	48.2	1.2342
7.8	1.3086	15.9	1.2867	24	1.2177	32.1	1.2311	40.2	1.2256	48.3	1.2342
7.9	1.3074	16	1.2818	24.1	1.2177	32.2	1.2323	40.3	1.2256	48.4	1.2342
8	1.3092	16.1	1.2793	24.2	1.222	32.3	1.2323	40.4	1.2256	48.5	1.2366

Time (s)	Voltage (V)
48.6	1.2366
48.7	1.2354
48.8	1.2348
48.9	1.2348
49	1.2342
49.1	1.2336
49.2	1.2348
49.3	1.2342
49.4	1.2348
49.5	1.236
49.6	1.2354
49.7	1.2354
49.8	1.2329
49.9	1.2366
50	1.2342
50.1	1.2366
50.2	1.2366
50.3	1.2354
50.4	1.236
50.5	1.2348
50.6	1.2348
50.7	1.2348
50.8	1.2317
50.9	1.2311
51	1.2336
51.1	1.2329
51.2	1.2305
51.3	1.2305
51.4	1.2305
51.5	1.2305
51.6	1.2305
51.7	1.2275
51.8	1.2281
51.9	1.2287
52	1.2287
52.1	1.2293
52.2	1.2305
52.3	1.2287
52.4	1.2299
52.5	1.2281
52.6	1.2323
52.7	1.2317
52.8	1.2305
52.9	1.2305
53	1.2293
53.1	1.2293
53.2	1.2287
53.3	1.2287
53.4	1.2293
53.5	1.2299
53.6	1.2299
53.7	1.2305
53.8	1.2293
53.9	1.2293
54	1.2287
54.1	1.2287
54.2	1.2268
54.3	1.2268
54.4	1.2268
54.5	1.2287
54.6	1.2287
54.7	1.2299
54.8	1.2311
54.9	1.2299
55	1.2311
55.1	1.2305
55.2	1.2311
55.3	1.2323
55.4	1.2311
55.5	1.2299
55.6	1.2305
55.7	1.2323
55.8	1.2317
55.9	1.2299
56	1.2311
56.1	1.2317
56.2	1.2317
56.3	1.2317
56.4	1.2317
56.5	1.2323
56.6	1.2323

Time (s)	Voltage (V)
56.7	1.2323
56.8	1.2329
56.9	1.2317
57	1.2305
57.1	1.2311
57.2	1.2256
57.3	1.2214
57.4	1.2226
57.5	1.2232
57.6	1.2214
57.7	1.2207
57.8	1.222
57.9	1.2226
58	1.222
58.1	1.2226
58.2	1.2232
58.3	1.2238
58.4	1.2281
58.5	1.2305
58.6	1.2329
58.7	1.2311
58.8	1.2329
58.9	1.2354
59	1.2366
59.1	1.2354
59.2	1.2348
59.3	1.2342
59.4	1.2354
59.5	1.2354
59.6	1.236
59.7	1.236
59.8	1.2372
59.9	1.2366
60	1.2372

APPENDIX G.3

PARALLEL CONNECTION BETWEEN 1000 MILIFARAD CAPACITANCE OF ULTRACAPACITOR WITH ONE MANGANESE BATTERY

Time (s)	Voltage (V)	Time (s)	Voltage (V)	Time (s)	Voltage (V)	Time (s)	Voltage (V)	Time (s)	Voltage (V)	Time (s)	Voltage (V)
0	1.2598	8.1	1.3526	16.2	1.3526	24.3	1.3514	32.4	1.3477	40.5	1.3471
0.1	1.1963	8.2	1.3526	16.3	1.3526	24.4	1.352	32.5	1.3483	40.6	1.3465
0.2	1.2647	8.3	1.3526	16.4	1.3526	24.5	1.3495	32.6	1.3483	40.7	1.3477
0.3	1.2879	8.4	1.352	16.5	1.3526	24.6	1.352	32.7	1.3477	40.8	1.3465
0.4	1.2989	8.5	1.3526	16.6	1.3526	24.7	1.3514	32.8	1.3477	40.9	1.3471
0.5	1.3086	8.6	1.3526	16.7	1.3526	24.8	1.352	32.9	1.3477	41	1.3471
0.6	1.3135	8.7	1.3526	16.8	1.3526	24.9	1.3501	33	1.3477	41.1	1.3471
0.7	1.3178	8.8	1.3526	16.9	1.3526	25	1.3501	33.1	1.3477	41.2	1.3459
0.8	1.319	8.9	1.3526	17	1.3526	25.1	1.3507	33.2	1.3477	41.3	1.3471
0.9	1.3233	9	1.3526	17.1	1.3526	25.2	1.3507	33.3	1.3477	41.4	1.3465
1	1.3263	9.1	1.3526	17.2	1.3526	25.3	1.3507	33.4	1.3477	41.5	1.3465
1.1	1.3282	9.2	1.3526	17.3	1.3526	25.4	1.3514	33.5	1.3477	41.6	1.3471
1.2	1.3282	9.3	1.3526	17.4	1.3526	25.5	1.3501	33.6	1.3477	41.7	1.3459
1.3	1.3312	9.4	1.3526	17.5	1.3526	25.6	1.3477	33.7	1.3477	41.8	1.3471
1.4	1.333	9.5	1.3526	17.6	1.3526	25.7	1.3501	33.8	1.3477	41.9	1.3465
1.5	1.333	9.6	1.3526	17.7	1.3526	25.8	1.3495	33.9	1.3477	42	1.3471
1.6	1.3337	9.7	1.3526	17.8	1.3526	25.9	1.3514	34	1.3477	42.1	1.3459
1.7	1.3355	9.8	1.3526	17.9	1.3526	26	1.3501	34.1	1.3477	42.2	1.3459
1.8	1.3379	9.9	1.3526	18	1.3526	26.1	1.3507	34.2	1.3477	42.3	1.3465
1.9	1.3379	10	1.3526	18.1	1.3526	26.2	1.3501	34.3	1.3477	42.4	1.3453
2	1.3379	10.1	1.3526	18.2	1.3526	26.3	1.3514	34.4	1.3477	42.5	1.3459
2.1	1.3379	10.2	1.3526	18.3	1.3526	26.4	1.3495	34.5	1.3477	42.6	1.3453
2.2	1.3392	10.3	1.3526	18.4	1.3526	26.5	1.3495	34.6	1.3477	42.7	1.3446
2.3	1.341	10.4	1.352	18.5	1.3526	26.6	1.3501	34.7	1.3477	42.8	1.3465
2.4	1.3422	10.5	1.3526	18.6	1.3526	26.7	1.3483	34.8	1.3477	42.9	1.3459
2.5	1.3428	10.6	1.3526	18.7	1.3526	26.8	1.3495	34.9	1.3477	43	1.3471
2.6	1.3428	10.7	1.3526	18.8	1.3526	26.9	1.3514	35	1.3477	43.1	1.3459
2.7	1.3428	10.8	1.3526	18.9	1.3526	27	1.3514	35.1	1.3477	43.2	1.3453
2.8	1.3428	10.9	1.3526	19	1.3526	27.1	1.3514	35.2	1.3477	43.3	1.3459
2.9	1.3434	11	1.3526	19.1	1.352	27.2	1.3501	35.3	1.3477	43.4	1.3459
3	1.344	11.1	1.3526	19.2	1.3526	27.3	1.3495	35.4	1.3477	43.5	1.3453
3.1	1.3453	11.2	1.3526	19.3	1.3526	27.4	1.3501	35.5	1.3477	43.6	1.3453
3.2	1.3459	11.3	1.3526	19.4	1.3526	27.5	1.3501	35.6	1.3477	43.7	1.3465
3.3	1.3471	11.4	1.3532	19.5	1.3514	27.6	1.3489	35.7	1.3477	43.8	1.3446
3.4	1.3477	11.5	1.3526	19.6	1.3526	27.7	1.3483	35.8	1.3477	43.9	1.3453
3.5	1.3471	11.6	1.3532	19.7	1.3526	27.8	1.3495	35.9	1.3477	44	1.3453
3.6	1.3471	11.7	1.3526	19.8	1.3526	27.9	1.3489	36	1.3477	44.1	1.3459
3.7	1.3477	11.8	1.3526	19.9	1.3526	28	1.3501	36.1	1.3477	44.2	1.3459
3.8	1.3477	11.9	1.3538	20	1.352	28.1	1.3501	36.2	1.3477	44.3	1.3453
3.9	1.3477	12	1.3526	20.1	1.3526	28.2	1.3495	36.3	1.3477	44.4	1.3446
4	1.3477	12.1	1.3532	20.2	1.3526	28.3	1.3495	36.4	1.3477	44.5	1.3453
4.1	1.3477	12.2	1.3526	20.3	1.3507	28.4	1.3489	36.5	1.3477	44.6	1.3446
4.2	1.3477	12.3	1.3526	20.4	1.3526	28.5	1.3495	36.6	1.3477	44.7	1.3446
4.3	1.3477	12.4	1.3532	20.5	1.3526	28.6	1.3483	36.7	1.3477	44.8	1.3453
4.4	1.3477	12.5	1.3526	20.6	1.3526	28.7	1.3495	36.8	1.3477	44.9	1.3446
4.5	1.3477	12.6	1.3526	20.7	1.3526	28.8	1.3483	36.9	1.3477	45	1.3453
4.6	1.3483	12.7	1.3532	20.8	1.3526	28.9	1.3489	37	1.3477	45.1	1.3453
4.7	1.3489	12.8	1.3526	20.9	1.352	29	1.3483	37.1	1.3477	45.2	1.3446
4.8	1.3489	12.9	1.3526	21	1.3526	29.1	1.3489	37.2	1.3477	45.3	1.3453
4.9	1.3483	13	1.3526	21.1	1.3526	29.2	1.3483	37.3	1.3477	45.4	1.3453
5	1.3483	13.1	1.3526	21.2	1.3526	29.3	1.3483	37.4	1.3477	45.5	1.3446
5.1	1.3495	13.2	1.3526	21.3	1.352	29.4	1.3501	37.5	1.3471	45.6	1.3434
5.2	1.3507	13.3	1.3532	21.4	1.3526	29.5	1.3483	37.6	1.3477	45.7	1.3446
5.3	1.3489	13.4	1.3526	21.5	1.3526	29.6	1.3483	37.7	1.3477	45.8	1.344
5.4	1.3501	13.5	1.3526	21.6	1.3526	29.7	1.3489	37.8	1.3477	45.9	1.344
5.5	1.3507	13.6	1.3526	21.7	1.352	29.8	1.3483	37.9	1.3477	46	1.3434
5.6	1.352	13.7	1.3526	21.8	1.3526	29.9	1.3489	38	1.3477	46.1	1.344
5.7	1.352	13.8	1.3532	21.9	1.3526	30	1.3495	38.1	1.3477	46.2	1.3434
5.8	1.3526	13.9	1.3532	22	1.3514	30.1	1.3489	38.2	1.3477	46.3	1.344
5.9	1.352	14	1.3526	22.1	1.3507	30.2	1.3483	38.3	1.3477	46.4	1.3434
6	1.352	14.1	1.3526	22.2	1.352	30.3	1.3483	38.4	1.3477	46.5	1.344
6.1	1.3526	14.2	1.3532	22.3	1.352	30.4	1.3477	38.5	1.3477	46.6	1.3434
6.2	1.3526	14.3	1.3526	22.4	1.352	30.5	1.3489	38.6	1.3477	46.7	1.344
6.3	1.3526	14.4	1.3526	22.5	1.352	30.6	1.3489	38.7	1.3477	46.8	1.3434
6.4	1.3526	14.5	1.3526	22.6	1.352	30.7	1.3483	38.8	1.3477	46.9	1.344
6.5	1.3526	14.6	1.3526	22.7	1.3526	30.8	1.3477	38.9	1.3477	47	1.3434
6.6	1.3526	14.7	1.3532	22.8	1.352	30.9	1.3483	39	1.3471	47.1	1.3446
6.7	1.352	14.8	1.3532	22.9	1.352	31	1.3483	39.1	1.3477	47.2	1.3446
6.8	1.3526	14.9	1.3526	23	1.352	31.1	1.3483	39.2	1.3477	47.3	1.344
6.9	1.3526	15	1.3526	23.1	1.352	31.2	1.3483	39.3	1.3477	47.4	1.3434
7	1.352	15.1	1.3526	23.2	1.3507	31.3	1.3477	39.4	1.3477	47.5	1.3434
7.1	1.352	15.2	1.3526	23.3	1.3507	31.4	1.3483	39.5	1.3477	47.6	1.3446
7.2	1.3526	15.3	1.352	23.4	1.3514	31.5	1.3477	39.6	1.3471	47.7	1.3428
7.3	1.3526	15.4	1.3526	23.5	1.352	31.6	1.3477	39.7	1.3477	47.8	1.3434
7.4	1.3526	15.5	1.3526	23.6	1.352	31.7	1.3483	39.8	1.3477	47.9	1.344
7.5	1.3526	15.6	1.3526	23.7	1.3526	31.8	1.3483	39.9	1.3477	48	1.3428
7.6	1.3526	15.7	1.3526	23.8	1.3507	31.9	1.3477	40	1.3471	48.1	1.3434
7.7	1.3526	15.8	1.3526	23.9	1.3526	32	1.3477	40.1	1.3477	48.2	1.3434
7.8	1.3526	15.9	1.3526	24	1.352	32.1	1.3477	40.2	1.3471	48.3	1.3434
7.9	1.3526	16	1.3526	24.1	1.3514	32.2	1.3477	40.3	1.3459	48.4	1.3434
8	1.3526	16.1	1.3526	24.2	1.3507	32.3	1.3477	40.4	1.3471	48.5	1.3428

Time (s)	Voltage (V)
48.6	1.3428
48.7	1.3428
48.8	1.3422
48.9	1.3428
49	1.3428
49.1	1.3428
49.2	1.3428
49.3	1.3428
49.4	1.3428
49.5	1.3434
49.6	1.3428
49.7	1.3428
49.8	1.3428
49.9	1.3428
50	1.3428
50.1	1.3428
50.2	1.3428
50.3	1.3428
50.4	1.3428
50.5	1.3428
50.6	1.3428
50.7	1.3428
50.8	1.3428
50.9	1.3428
51	1.3428
51.1	1.3428
51.2	1.3428
51.3	1.3428
51.4	1.3428
51.5	1.3428
51.6	1.3428
51.7	1.3428
51.8	1.3428
51.9	1.3428
52	1.3428
52.1	1.3422
52.2	1.3428
52.3	1.3428
52.4	1.3422
52.5	1.3428
52.6	1.3428
52.7	1.3428
52.8	1.3422
52.9	1.3428
53	1.3428
53.1	1.3428
53.2	1.3422
53.3	1.3422
53.4	1.3428
53.5	1.3422
53.6	1.3428
53.7	1.3428
53.8	1.3422
53.9	1.3428
54	1.3422
54.1	1.3422
54.2	1.3422
54.3	1.3422
54.4	1.3422
54.5	1.3422
54.6	1.3422
54.7	1.3416
54.8	1.3422
54.9	1.3416
55	1.3422
55.1	1.3422
55.2	1.3428
55.3	1.3422
55.4	1.3428
55.5	1.3404
55.6	1.3416
55.7	1.341
55.8	1.341
55.9	1.3416
56	1.3416
56.1	1.3422
56.2	1.341
56.3	1.3416
56.4	1.3416
56.5	1.341
56.6	1.341

Time (s)	Voltage (V)
56.7	1.341
56.8	1.3404
56.9	1.3416
57	1.3404
57.1	1.341
57.2	1.3404
57.3	1.3422
57.4	1.3398
57.5	1.3404
57.6	1.3392
57.7	1.3404
57.8	1.3398
57.9	1.3392
58	1.3385
58.1	1.3392
58.2	1.3392
58.3	1.3398
58.4	1.3398
58.5	1.3392
58.6	1.3398
58.7	1.3385
58.8	1.3385
58.9	1.3392
59	1.3404
59.1	1.3385
59.2	1.3385
59.3	1.3385
59.4	1.3385
59.5	1.3385
59.6	1.3379
59.7	1.3379
59.8	1.3379
59.9	1.3392
60	1.3398

APPENDIX G.4

PARALLEL CONNECTION BETWEEN 1500 MILIFARAD CAPACITANCE OF ULTRACAPACITOR WITH ONE MANGANESE BATTERY

Time (s)	Voltage (V)	Time (s)	Voltage (V)	Time (s)	Voltage (V)	Time (s)	Voltage (V)	Time (s)	Voltage (V)	Time (s)	Voltage (V)
0	1.0022	8.1	1.1237	16.2	1.2287	24.3	1.269	32.4	1.2702	40.5	1.2726
0.1	1.1005	8.2	1.1335	16.3	1.2305	24.4	1.2659	32.5	1.2708	40.6	1.2726
0.2	1.2409	8.3	1.1286	16.4	1.2305	24.5	1.2647	32.6	1.2696	40.7	1.2726
0.3	1.25	8.4	1.1359	16.5	1.2305	24.6	1.2641	32.7	1.2702	40.8	1.2726
0.4	1.2513	8.5	1.1444	16.6	1.2305	24.7	1.2647	32.8	1.272	40.9	1.2732
0.5	1.2506	8.6	1.1347	16.7	1.2342	24.8	1.2647	32.9	1.2714	41	1.2732
0.6	1.2519	8.7	1.1353	16.8	1.2354	24.9	1.2647	33	1.2714	41.1	1.2751
0.7	1.2568	8.8	1.1377	16.9	1.2336	25	1.2653	33.1	1.2708	41.2	1.2751
0.8	1.2568	8.9	1.1371	17	1.2323	25.1	1.2683	33.2	1.2702	41.3	1.2745
0.9	1.2549	9	1.1341	17.1	1.2299	25.2	1.2696	33.3	1.272	41.4	1.2745
1	1.2513	9.1	1.1377	17.2	1.2287	25.3	1.2696	33.4	1.2726	41.5	1.2745
1.1	1.2555	9.2	1.1328	17.3	1.2305	25.4	1.2696	33.5	1.2714	41.6	1.2745
1.2	1.2592	9.3	1.1286	17.4	1.2342	25.5	1.2714	33.6	1.272	41.7	1.2751
1.3	1.2604	9.4	1.1274	17.5	1.2354	25.6	1.2726	33.7	1.272	41.8	1.2738
1.4	1.2586	9.5	1.1035	17.6	1.2366	25.7	1.2745	33.8	1.2738	41.9	1.2745
1.5	1.258	9.6	1.0993	17.7	1.236	25.8	1.2745	33.9	1.2745	42	1.2745
1.6	1.2598	9.7	1.0987	17.8	1.2354	25.9	1.2745	34	1.2745	42.1	1.2757
1.7	1.258	9.8	1.1017	17.9	1.236	26	1.2732	34.1	1.2745	42.2	1.2751
1.8	1.2568	9.9	1.1035	18	1.2397	26.1	1.2726	34.2	1.2732	42.3	1.2745
1.9	1.2531	10	1.1139	18.1	1.2397	26.2	1.2708	34.3	1.2738	42.4	1.2757
2	1.2506	10.1	1.1182	18.2	1.2403	26.3	1.2708	34.4	1.2745	42.5	1.2763
2.1	1.2488	10.2	1.1231	18.3	1.2409	26.4	1.2708	34.5	1.2726	42.6	1.2751
2.2	1.2506	10.3	1.1206	18.4	1.2445	26.5	1.2714	34.6	1.2732	42.7	1.2757
2.3	1.2549	10.4	1.1231	18.5	1.2445	26.6	1.2708	34.7	1.272	42.8	1.2751
2.4	1.2598	10.5	1.1347	18.6	1.2452	26.7	1.2714	34.8	1.2708	42.9	1.2757
2.5	1.2598	10.6	1.1383	18.7	1.2433	26.8	1.2726	34.9	1.2702	43	1.2763
2.6	1.2537	10.7	1.1426	18.8	1.2445	26.9	1.272	35	1.2696	43.1	1.2751
2.7	1.25	10.8	1.1475	18.9	1.2488	27	1.272	35.1	1.2696	43.2	1.2763
2.8	1.25	10.9	1.1597	19	1.25	27.1	1.2732	35.2	1.2696	43.3	1.2769
2.9	1.25	11	1.164	19.1	1.2506	27.2	1.272	35.3	1.2696	43.4	1.2763
3	1.2537	11.1	1.1646	19.2	1.2543	27.3	1.272	35.4	1.2696	43.5	1.2763
3.1	1.2506	11.2	1.1621	19.3	1.2549	27.4	1.2714	35.5	1.2702	43.6	1.2763
3.2	1.2464	11.3	1.1591	19.4	1.2592	27.5	1.2708	35.6	1.272	43.7	1.2775
3.3	1.2439	11.4	1.1628	19.5	1.2592	27.6	1.2714	35.7	1.2714	43.8	1.2775
3.4	1.2403	11.5	1.1573	19.6	1.2598	27.7	1.2714	35.8	1.2708	43.9	1.2787
3.5	1.2384	11.6	1.1579	19.7	1.2598	27.8	1.2726	35.9	1.2696	44	1.2781
3.6	1.2354	11.7	1.167	19.8	1.2604	27.9	1.2714	36	1.2702	44.1	1.2781
3.7	1.2427	11.8	1.1652	19.9	1.261	28	1.2714	36.1	1.2714	44.2	1.2787
3.8	1.2391	11.9	1.1695	20	1.2635	28.1	1.2708	36.2	1.2708	44.3	1.2781
3.9	1.2305	12	1.1731	20.1	1.2647	28.2	1.2702	36.3	1.2726	44.4	1.2781
4	1.2305	12.1	1.1719	20.2	1.2659	28.3	1.2702	36.4	1.272	44.5	1.2787
4.1	1.2311	12.2	1.1719	20.3	1.2677	28.4	1.2696	36.5	1.272	44.6	1.2787
4.2	1.2317	12.3	1.1713	20.4	1.2653	28.5	1.2696	36.6	1.2726	44.7	1.2793
4.3	1.2372	12.4	1.1719	20.5	1.2647	28.6	1.2696	36.7	1.272	44.8	1.2769
4.4	1.2403	12.5	1.1756	20.6	1.2635	28.7	1.2702	36.8	1.2714	44.9	1.2793
4.5	1.2372	12.6	1.1768	20.7	1.261	28.8	1.2708	36.9	1.2708	45	1.2793
4.6	1.2354	12.7	1.1835	20.8	1.2604	28.9	1.2696	37	1.2708	45.1	1.2787
4.7	1.2354	12.8	1.1914	20.9	1.2598	29	1.2696	37.1	1.2714	45.2	1.2787
4.8	1.2354	12.9	1.1963	21	1.2598	29.1	1.2683	37.2	1.2702	45.3	1.2793
4.9	1.2311	13	1.1994	21.1	1.2598	29.2	1.2677	37.3	1.2714	45.4	1.2787
5	1.2275	13.1	1.2043	21.2	1.2592	29.3	1.2671	37.4	1.2714	45.5	1.2793
5.1	1.2177	13.2	1.2091	21.3	1.2598	29.4	1.2659	37.5	1.2708	45.6	1.2793
5.2	1.1982	13.3	1.2128	21.4	1.2586	29.5	1.2659	37.6	1.2702	45.7	1.2793
5.3	1.0492	13.4	1.214	21.5	1.2555	29.6	1.2671	37.7	1.2726	45.8	1.2793
5.4	1.0987	13.5	1.214	21.6	1.2549	29.7	1.2683	37.8	1.2714	45.9	1.2793
5.5	1.0987	13.6	1.211	21.7	1.2549	29.8	1.269	37.9	1.272	46	1.2793
5.6	1.1267	13.7	1.211	21.8	1.2549	29.9	1.2677	38	1.2738	46.1	1.2793
5.7	1.1328	13.8	1.2061	21.9	1.2549	30	1.2683	38.1	1.2738	46.2	1.2781
5.8	1.1377	13.9	1.2043	22	1.2549	30.1	1.2683	38.2	1.2745	46.3	1.2793
5.9	1.1341	14	1.2116	22.1	1.2549	30.2	1.2677	38.3	1.2745	46.4	1.2787
6	1.1292	14.1	1.2159	22.2	1.2549	30.3	1.2683	38.4	1.2745	46.5	1.2793
6.1	1.1182	14.2	1.2146	22.3	1.2549	30.4	1.2671	38.5	1.2732	46.6	1.2793
6.2	1.045	14.3	1.211	22.4	1.2549	30.5	1.2696	38.6	1.2738	46.7	1.2793
6.3	1.0639	14.4	1.2104	22.5	1.2549	30.6	1.2702	38.7	1.2738	46.8	1.2793
6.4	1.0773	14.5	1.2085	22.6	1.2555	30.7	1.2696	38.8	1.2732	46.9	1.2793
6.5	1.084	14.6	1.211	22.7	1.2555	30.8	1.2696	38.9	1.2738	47	1.2793
6.6	1.084	14.7	1.2134	22.8	1.2549	30.9	1.2696	39	1.2732	47.1	1.2793
6.7	1.0828	14.8	1.2146	22.9	1.2561	31	1.2696	39.1	1.2732	47.2	1.2793
6.8	1.084	14.9	1.2134	23	1.2561	31.1	1.2696	39.2	1.2726	47.3	1.2793
6.9	1.0889	15	1.214	23.1	1.2598	31.2	1.2696	39.3	1.2732	47.4	1.2793
7	1.084	15.1	1.2159	23.2	1.2598	31.3	1.2702	39.4	1.2732	47.5	1.2793
7.1	1.0865	15.2	1.2159	23.3	1.2598	31.4	1.2708	39.5	1.2726	47.6	1.2793
7.2	1.0938	15.3	1.2171	23.4	1.2604	31.5	1.2696	39.6	1.2726	47.7	1.2793
7.3	1.1005	15.4	1.2201	23.5	1.2616	31.6	1.2696	39.7	1.2732	47.8	1.2793
7.4	1.1011	15.5	1.2207	23.6	1.2635	31.7	1.2696	39.8	1.2738	47.9	1.2793
7.5	1.1072	15.6	1.2232	23.7	1.2647	31.8	1.2702	39.9	1.2745	48	1.2793
7.6	1.0993	15.7	1.225	23.8	1.2647	31.9	1.2708	40	1.2738	48.1	1.2799
7.7	1.1127	15.8	1.2256	23.9	1.2647	32	1.2714	40.1	1.272	48.2	1.2806
7.8	1.1206	15.9	1.2256	24	1.2647	32.1	1.2714	40.2	1.272	48.3	1.2799
7.9	1.1121	16	1.225	24.1	1.2647	32.2	1.272	40.3	1.2738	48.4	1.2818
8	1.1158	16.1	1.225	24.2	1.2653	32.3	1.2702	40.4	1.2732	48.5	1.2818

Time (s)	Voltage (V)
48.6	1.2818
48.7	1.283
48.8	1.2836
48.9	1.2842
49	1.2842
49.1	1.2842
49.2	1.2867
49.3	1.2885
49.4	1.2885
49.5	1.2891
49.6	1.2891
49.7	1.2897
49.8	1.2897
49.9	1.2891
50	1.2903
50.1	1.2891
50.2	1.2891
50.3	1.2897
50.4	1.2903
50.5	1.2891
50.6	1.2891
50.7	1.2897
50.8	1.2903
50.9	1.2897
51	1.2897
51.1	1.2891
51.2	1.2897
51.3	1.2897
51.4	1.2909
51.5	1.2903
51.6	1.2909
51.7	1.2897
51.8	1.2897
51.9	1.2897
52	1.2903
52.1	1.2897
52.2	1.2909
52.3	1.2897
52.4	1.2897
52.5	1.2891
52.6	1.2891
52.7	1.2891
52.8	1.2891
52.9	1.2891
53	1.2891
53.1	1.2891
53.2	1.2891
53.3	1.2885
53.4	1.2885
53.5	1.2873
53.6	1.2873
53.7	1.2879
53.8	1.2867
53.9	1.2867
54	1.2854
54.1	1.2867
54.2	1.2873
54.3	1.2848
54.4	1.2867
54.5	1.2867
54.6	1.2873
54.7	1.286
54.8	1.2867
54.9	1.286
55	1.2879
55.1	1.2879
55.2	1.2879
55.3	1.2885
55.4	1.2879
55.5	1.2885
55.6	1.2879
55.7	1.2867
55.8	1.2867
55.9	1.2873
56	1.286
56.1	1.2842
56.2	1.2842
56.3	1.2842
56.4	1.283
56.5	1.2824
56.6	1.2824

Time (s)	Voltage (V)
56.7	1.2818
56.8	1.2806
56.9	1.2799
57	1.2793
57.1	1.2793
57.2	1.2793
57.3	1.2793
57.4	1.2793
57.5	1.2793
57.6	1.2799
57.7	1.2793
57.8	1.2806
57.9	1.2812
58	1.2812
58.1	1.2806
58.2	1.2806
58.3	1.2812
58.4	1.2806
58.5	1.2799
58.6	1.2806
58.7	1.2799
58.8	1.2818
58.9	1.2806
59	1.2799
59.1	1.2799
59.2	1.2806
59.3	1.2793
59.4	1.2799
59.5	1.2806
59.6	1.2806
59.7	1.2806
59.8	1.2806
59.9	1.2793
60	1.2806

APPENDIX G.5

PARALLEL CONNECTION BETWEEN 22000 MILIFARAD CAPACITANCE OF ULTRACAPACITOR WITH ONE MANGANESE BATTERY

Time (s)	Voltage (V)
0	0.8246
0.1	0.7715
0.2	0.7685
0.3	0.8045
0.4	0.8008
0.5	0.7434
0.6	0.7233
0.7	0.7221
0.8	0.7001
0.9	0.6696
1	0.6604
1.1	0.6543
1.2	0.6519
1.3	0.6543
1.4	0.6531
1.5	0.6537
1.6	0.6494
1.7	0.6525
1.8	0.6598
1.9	0.6592
2	0.6604
2.1	0.661
2.2	0.6641
2.3	0.6684
2.4	0.6647
2.5	0.6659
2.6	0.669
2.7	0.672
2.8	0.6738
2.9	0.6696
3	0.6714
3.1	0.6738
3.2	0.6738
3.3	0.6738
3.4	0.6769
3.5	0.6757
3.6	0.6781
3.7	0.6787
3.8	0.6806
3.9	0.683
4	0.6836
4.1	0.6867
4.2	0.6885
4.3	0.6836
4.4	0.6818
4.5	0.6757
4.6	0.669
4.7	0.6623
4.8	0.65
4.9	0.6464
5	0.6446
5.1	0.6458
5.2	0.647
5.3	0.6494
5.4	0.6537
5.5	0.6561
5.6	0.661
5.7	0.6647
5.8	0.669
5.9	0.6732
6	0.6769
6.1	0.6806
6.2	0.6836
6.3	0.6885
6.4	0.6915
6.5	0.6934
6.6	0.6983
6.7	0.7031
6.8	0.7038
6.9	0.708
7	0.7099
7.1	0.7172
7.2	0.7221
7.3	0.7239
7.4	0.7257
7.5	0.7276
7.6	0.7276
7.7	0.7324
7.8	0.7361
7.9	0.7379
8	0.7434

Time (s)	Voltage (V)
8.1	0.7465
8.2	0.7477
8.3	0.752
8.4	0.7538
8.5	0.7587
8.6	0.7617
8.7	0.7654
8.8	0.7685
8.9	0.7727
9	0.7776
9.1	0.7801
9.2	0.7813
9.3	0.7813
9.4	0.7825
9.5	0.7862
9.6	0.788
9.7	0.7904
9.8	0.791
9.9	0.791
10	0.7904
10.1	0.791
10.2	0.791
10.3	0.791
10.4	0.7959
10.5	0.799
10.6	0.8008
10.7	0.8045
10.8	0.8008
10.9	0.802
11	0.8051
11.1	0.8063
11.2	0.8094
11.3	0.8081
11.4	0.8094
11.5	0.8106
11.6	0.8112
11.7	0.813
11.8	0.8155
11.9	0.8197
12	0.8203
12.1	0.8203
12.2	0.8216
12.3	0.8252
12.4	0.8271
12.5	0.8301
12.6	0.8313
12.7	0.835
12.8	0.8386
12.9	0.8386
13	0.8399
13.1	0.8441
13.2	0.8448
13.3	0.8478
13.4	0.8502
13.5	0.8551
13.6	0.8576
13.7	0.8594
13.8	0.8618
13.9	0.8649
14	0.8649
14.1	0.8643
14.2	0.8667
14.3	0.8692
14.4	0.8704
14.5	0.8741
14.6	0.8741
14.7	0.8765
14.8	0.8783
14.9	0.8789
15	0.8832
15.1	0.885
15.2	0.8875
15.3	0.8887
15.4	0.8887
15.5	0.8936
15.6	0.8972
15.7	0.8985
15.8	0.8985
15.9	0.8985
16	0.8997
16.1	0.9015

Time (s)	Voltage (V)
16.2	0.9033
16.3	0.9033
16.4	0.9033
16.5	0.904
16.6	0.9076
16.7	0.9095
16.8	0.9119
16.9	0.9131
17	0.9137
17.1	0.9156
17.2	0.9168
17.3	0.9162
17.4	0.9162
17.5	0.918
17.6	0.918
17.7	0.9198
17.8	0.921
17.9	0.921
18	0.9229
18.1	0.9235
18.2	0.9247
18.3	0.9278
18.4	0.9278
18.5	0.9278
18.6	0.932
18.7	0.9345
18.8	0.9351
18.9	0.9375
19	0.9375
19.1	0.9387
19.2	0.94
19.3	0.9424
19.4	0.9424
19.5	0.9436
19.6	0.9467
19.7	0.9473
19.8	0.951
19.9	0.9522
20	0.9522
20.1	0.9565
20.2	0.9571
20.3	0.9571
20.4	0.9583
20.5	0.9583
20.6	0.9583
20.7	0.9595
20.8	0.9607
20.9	0.9619
21	0.9619
21.1	0.9619
21.2	0.9619
21.3	0.9626
21.4	0.9644
21.5	0.9656
21.6	0.9668
21.7	0.9668
21.8	0.9668
21.9	0.9674
22	0.9668
22.1	0.9668
22.2	0.9674
22.3	0.9693
22.4	0.9711
22.5	0.9717
22.6	0.9723
22.7	0.9723
22.8	0.9735
22.9	0.9754
23	0.9766
23.1	0.9766
23.2	0.9766
23.3	0.979
23.4	0.9803
23.5	0.9815
23.6	0.9827
23.7	0.9857
23.8	0.9857
23.9	0.987
24	0.9864
24.1	0.9882
24.2	0.9906

Time (s)	Voltage (V)
24.3	0.9912
24.4	0.9906
24.5	0.9912
24.6	0.9919
24.7	0.9931
24.8	0.9925
24.9	0.9937
25	0.9949
25.1	0.9961
25.2	0.9961
25.3	0.9961
25.4	0.9961
25.5	0.9961
25.6	0.9961
25.7	0.9967
25.8	0.998
25.9	0.9973
26	0.998
26.1	0.9998
26.2	0.998
26.3	0.9998
26.4	0.9998
26.5	1.0004
26.6	1.001
26.7	1.001
26.8	1.001
26.9	1.0022
27	1.0034
27.1	1.0047
27.2	1.0059
27.3	1.0059
27.4	1.0065
27.5	1.0059
27.6	1.0071
27.7	1.0077
27.8	1.0108
27.9	1.0114
28	1.0114
28.1	1.0132
28.2	1.0138
28.3	1.0157
28.4	1.015
28.5	1.0157
28.6	1.0157
28.7	1.0163
28.8	1.0169
28.9	1.0199
29	1.0181
29.1	1.0199
29.2	1.0199
29.3	1.0205
29.4	1.0205
29.5	1.0218
29.6	1.0218
29.7	1.0236
29.8	1.0242
29.9	1.0254
30	1.0254
30.1	1.0248
30.2	1.0254
30.3	1.0254
30.4	1.0285
30.5	1.0285
30.6	1.0303
30.7	1.0303
30.8	1.0309
30.9	1.0303
31	1.0303
31.1	1.034
31.2	1.034
31.3	1.0346
31.4	1.0352
31.5	1.0352
31.6	1.0358
31.7	1.0352
31.8	1.037
31.9	1.0382
32	1.0389
32.1	1.0395
32.2	1.0401
32.3	1.0401

Time (s)	Voltage (V)
32.4	1.0401
32.5	1.0407
32.6	1.0407
32.7	1.0413
32.8	1.0431
32.9	1.045
33	1.045
33.1	1.045
33.2	1.045
33.3	1.045
33.4	1.0456
33.5	1.0468
33.6	1.0486
33.7	1.0486
33.8	1.0498
33.9	1.0504
34	1.0504
34.1	1.0504
34.2	1.0529
34.3	1.0529
34.4	1.0541
34.5	1.0547
34.6	1.0547
34.7	1.0547
34.8	1.0553
34.9	1.0547
35	1.0572
35.1	1.0566
35.2	1.0578
35.3	1.0578
35.4	1.059
35.5	1.0596
35.6	1.0596
35.7	1.059
35.8	1.0596
35.9	1.0596
36	1.0602
36.1	1.0608
36.2	1.0633
36.3	1.0627
36.4	1.0645
36.5	1.0645
36.6	1.0645
36.7	1.0645
36.8	1.0645
36.9	1.0645
37	1.0645
37.1	1.0669
37.2	1.0657
37.3	1.0694
37.4	1.0694
37.5	1.0694
37.6	1.07
37.7	1.0706
37.8	1.0706
37.9	1.0718
38	1.073
38.1	1.0743
38.2	1.0736
38.3	1.0743
38.4	1.0743
38.5	1.0743
38.6	1.0749
38.7	1.0755
38.8	1.0755
38.9	1.0767
39	1.0785
39.1	1.0779
39.2	1.0791
39.3	1.0791
39.4	1.0791
39.5	1.0797
39.6	1.0791
39.7	1.0804
39.8	1.0816
39.9	1.0834
40	1.084
40.1	1.084
40.2	1.084
40.3	1.084
40.4	1.084

Time (s)	Voltage (V)
40.5	1.0852
40.6	1.0846
40.7	1.0871
40.8	1.0871
40.9	1.0883
41	1.0895
41.1	1.0889
41.2	1.0901
41.3	1.0907
41.4	1.0907
41.5	1.0932
41.6	1.0926
41.7	1.0938
41.8	1.0938
41.9	1.0938
42	1.0938
42.1	1.0944
42.2	1.0938
42.3	1.0944
42.4	1.095
42.5	1.0968
42.6	1.0962
42.7	1.0981
42.8	1.0968
42.9	1.0987
43	1.0987
43.1	1.0987
43.2	1.0987
43.3	1.0987
43.4	1.0993
43.5	1.0993
43.6	1.1011
43.7	1.1011
43.8	1.1023
43.9	1.1029
44	1.1023
44.1	1.1029
44.2	1.1035
44.3	1.1035
44.4	1.1035
44.5	1.1035
44.6	1.1042
44.7	1.1048
44.8	1.1042
44.9	1.1066
45	1.1066
45.1	1.1072
45.2	1.1078
45.3	1.1084
45.4	1.1084
45.5	1.1084
45.6	1.109
45.7	1.1103
45.8	1.1103
45.9	1.1109
46	1.1115
46.1	1.1127
46.2	1.1133
46.3	1.1133
46.4	1.1133
46.5	1.1133
46.6	1.1133
46.7	1.1133
46.8	1.1151
46.9	1.1151
47	1.1151
47.1	1.1158
47.2	1.1176
47.3	1.1176
47.4	1.1182
47.5	1.1182
47.6	1.1182
47.7	1.1182
47.8	1.1194
47.9	1.1188
48	1.12
48.1	1.1213
48.2	1.1225
48.3	1.1225
48.4	1.1231
48.5	1.1231

Time (s)	Voltage (V)
48.6	1.1231
48.7	1.1231
48.8	1.1231
48.9	1.1231
49	1.1237
49.1	1.1243
49.2	1.1255
49.3	1.1249
49.4	1.1255
49.5	1.1267
49.6	1.1274
49.7	1.1274
49.8	1.128
49.9	1.1286
50	1.128
50.1	1.1292
50.2	1.1304
50.3	1.1304
50.4	1.1316
50.5	1.1328
50.6	1.1328
50.7	1.1328
50.8	1.1328
50.9	1.1328
51	1.1328
51.1	1.1328
51.2	1.1328
51.3	1.1328
51.4	1.1335
51.5	1.1335
51.6	1.1341
51.7	1.1365
51.8	1.1365
51.9	1.1365
52	1.1365
52.1	1.1377
52.2	1.1377
52.3	1.1377
52.4	1.1377
52.5	1.1377
52.6	1.1383
52.7	1.1396
52.8	1.1396
52.9	1.1396
53	1.1408
53.1	1.1408
53.2	1.1408
53.3	1.142
53.4	1.1426
53.5	1.1426
53.6	1.1426
53.7	1.1426
53.8	1.1426
53.9	1.1426
54	1.1432
54.1	1.1432
54.2	1.1438
54.3	1.1444
54.4	1.1432
54.5	1.1457
54.6	1.1457
54.7	1.1463
54.8	1.1475
54.9	1.1475
55	1.1475
55.1	1.1469
55.2	1.1475
55.3	1.1493
55.4	1.1481
55.5	1.1493
55.6	1.1493
55.7	1.1512
55.8	1.1505
55.9	1.1524
56	1.1518
56.1	1.1524
56.2	1.1524
56.3	1.1524
56.4	1.153
56.5	1.1548
56.6	1.1536

Time (s)	Voltage (V)
56.7	1.1524
56.8	1.1542
56.9	1.1554
57	1.1542
57.1	1.1567
57.2	1.1573
57.3	1.1573
57.4	1.1573
57.5	1.1573
57.6	1.1579
57.7	1.1573
57.8	1.1573
57.9	1.1579
58	1.1579
58.1	1.1591
58.2	1.1591
58.3	1.1603
58.4	1.1609
58.5	1.1597
58.6	1.1609
58.7	1.1621
58.8	1.1609
58.9	1.1615
59	1.1615
59.1	1.1621
59.2	1.1621
59.3	1.1621
59.4	1.1621
59.5	1.1628
59.6	1.1628
59.7	1.1628
59.8	1.1634
59.9	1.1634
60	1.1646

APPENDIX H

THE DATA SHEETS OF THE VOLTAGE ACROSS THE LOAD FOR THE FIRST ONE MINUTE FOR TWO MANGANESE BATTERIES CIRCUIT ARRANGEMENT

APPENDIX H.1

BATTERY-ONLY CIRCUIT ARRANGEMENT FOR TWO MANGANESE BATTERIES CIRCUIT ARRANGEMENT

Time (s)	Voltage (V)	Time (s)	Voltage (V)	Time (s)	Voltage (V)	Time (s)	Voltage (V)	Time (s)	Voltage (V)	Time (s)	Voltage (V)
0	2.6826	8.1	2.7308	16.2	2.718	24.3	2.6972	32.4	2.6826	40.5	2.6661
0.1	2.729	8.2	2.7326	16.3	2.7161	24.4	2.6978	32.5	2.6801	40.6	2.6673
0.2	2.7577	8.3	2.7308	16.4	2.7149	24.5	2.6972	32.6	2.6795	40.7	2.6661
0.3	2.7564	8.4	2.7314	16.5	2.7161	24.6	2.6978	32.7	2.6795	40.8	2.6649
0.4	2.7436	8.5	2.7296	16.6	2.7168	24.7	2.6978	32.8	2.6795	40.9	2.6679
0.5	2.7564	8.6	2.7302	16.7	2.7149	24.8	2.6972	32.9	2.6795	41	2.6649
0.6	2.7631	8.7	2.7302	16.8	2.7155	24.9	2.6972	33	2.6795	41.1	2.6667
0.7	2.7601	8.8	2.729	16.9	2.7161	25	2.696	33.1	2.6789	41.2	2.6661
0.8	2.7613	8.9	2.7296	17	2.7149	25.1	2.6972	33.2	2.6789	41.3	2.6673
0.9	2.7534	9	2.7296	17.1	2.7149	25.2	2.6972	33.3	2.6789	41.4	2.6643
1	2.7528	9.1	2.7302	17.2	2.7149	25.3	2.696	33.4	2.6801	41.5	2.6655
1.1	2.7363	9.2	2.7277	17.3	2.7137	25.4	2.6954	33.5	2.6795	41.6	2.6655
1.2	2.7253	9.3	2.7302	17.4	2.7137	25.5	2.696	33.6	2.6777	41.7	2.6655
1.3	2.7192	9.4	2.729	17.5	2.7125	25.6	2.6948	33.7	2.6789	41.8	2.6649
1.4	2.6972	9.5	2.732	17.6	2.7119	25.7	2.6942	33.8	2.6783	41.9	2.6649
1.5	2.6868	9.6	2.7296	17.7	2.7131	25.8	2.6942	33.9	2.6783	42	2.663
1.6	2.6881	9.7	2.729	17.8	2.7131	25.9	2.6966	34	2.6771	42.1	2.6643
1.7	2.6966	9.8	2.7284	17.9	2.7107	26	2.693	34.1	2.6789	42.2	2.6643
1.8	2.7131	9.9	2.7265	18	2.7113	26.1	2.6923	34.2	2.6783	42.3	2.6643
1.9	2.7216	10	2.729	18.1	2.71	26.2	2.6936	34.3	2.6746	42.4	2.6643
2	2.7253	10.1	2.7271	18.2	2.7119	26.3	2.6936	34.4	2.6801	42.5	2.6612
2.1	2.721	10.2	2.7265	18.3	2.7119	26.4	2.6923	34.5	2.6765	42.6	2.6618
2.2	2.7027	10.3	2.7277	18.4	2.71	26.5	2.6923	34.6	2.6771	42.7	2.6649
2.3	2.7046	10.4	2.7271	18.5	2.7082	26.6	2.693	34.7	2.6771	42.8	2.6655
2.4	2.7131	10.5	2.7259	18.6	2.7088	26.7	2.6948	34.8	2.6759	42.9	2.6624
2.5	2.7204	10.6	2.7271	18.7	2.7082	26.8	2.6942	34.9	2.6783	43	2.6612
2.6	2.7186	10.7	2.7284	18.8	2.707	26.9	2.6923	35	2.6783	43.1	2.6637
2.7	2.7125	10.8	2.7277	18.9	2.707	27	2.6917	35.1	2.6765	43.2	2.6612
2.8	2.721	10.9	2.7296	19	2.7088	27.1	2.6923	35.2	2.6753	43.3	2.6624
2.9	2.7223	11	2.7259	19.1	2.7076	27.2	2.6911	35.3	2.6771	43.4	2.6612
3	2.7247	11.1	2.7277	19.2	2.707	27.3	2.6917	35.4	2.6759	43.5	2.6606
3.1	2.7265	11.2	2.7253	19.3	2.7076	27.4	2.6917	35.5	2.6753	43.6	2.663
3.2	2.7277	11.3	2.7247	19.4	2.7088	27.5	2.693	35.6	2.6759	43.7	2.6624
3.3	2.7271	11.4	2.7265	19.5	2.7064	27.6	2.6905	35.7	2.6765	43.8	2.66
3.4	2.721	11.5	2.7253	19.6	2.7076	27.7	2.6911	35.8	2.6759	43.9	2.6606
3.5	2.7186	11.6	2.7229	19.7	2.7064	27.8	2.6905	35.9	2.6753	44	2.663
3.6	2.7235	11.7	2.7241	19.8	2.7076	27.9	2.6893	36	2.6759	44.1	2.6618
3.7	2.7265	11.8	2.7265	19.9	2.7076	28	2.6911	36.1	2.674	44.2	2.6594
3.8	2.7235	11.9	2.7235	20	2.707	28.1	2.6893	36.2	2.6746	44.3	2.663
3.9	2.7296	12	2.7271	20.1	2.7058	28.2	2.6893	36.3	2.6753	44.4	2.66
4	2.7314	12.1	2.7247	20.2	2.7076	28.3	2.6868	36.4	2.6716	44.5	2.6606
4.1	2.7314	12.2	2.729	20.3	2.7058	28.4	2.6887	36.5	2.674	44.6	2.6618
4.2	2.732	12.3	2.7296	20.4	2.7052	28.5	2.6899	36.6	2.6753	44.7	2.6606
4.3	2.7277	12.4	2.7259	20.5	2.707	28.6	2.6862	36.7	2.6746	44.8	2.6594
4.4	2.7271	12.5	2.729	20.6	2.7052	28.7	2.6862	36.8	2.674	44.9	2.66
4.5	2.7253	12.6	2.7265	20.7	2.7046	28.8	2.6868	36.9	2.674	45	2.6594
4.6	2.7247	12.7	2.7265	20.8	2.7058	28.9	2.6868	37	2.6746	45.1	2.6588
4.7	2.7265	12.8	2.7229	20.9	2.7052	29	2.6868	37.1	2.674	45.2	2.66
4.8	2.7253	12.9	2.7247	21	2.7033	29.1	2.6868	37.2	2.674	45.3	2.6588
4.9	2.7192	13	2.7247	21.1	2.7046	29.2	2.6868	37.3	2.674	45.4	2.6582
5	2.721	13.1	2.7229	21.2	2.7033	29.3	2.6875	37.4	2.6753	45.5	2.66
5.1	2.7223	13.2	2.7229	21.3	2.7039	29.4	2.6856	37.5	2.674	45.6	2.6582
5.2	2.7223	13.3	2.7192	21.4	2.7021	29.5	2.6875	37.6	2.6728	45.7	2.66
5.3	2.7229	13.4	2.7216	21.5	2.7027	29.6	2.6862	37.7	2.6728	45.8	2.6588
5.4	2.7253	13.5	2.7241	21.6	2.7027	29.7	2.6844	37.8	2.6722	45.9	2.6588
5.5	2.7229	13.6	2.7204	21.7	2.7027	29.8	2.6862	37.9	2.674	46	2.6588
5.6	2.7253	13.7	2.7204	21.8	2.7021	29.9	2.685	38	2.6716	46.1	2.6582
5.7	2.7247	13.8	2.7223	21.9	2.7009	30	2.6838	38.1	2.6722	46.2	2.6576
5.8	2.7241	13.9	2.7198	22	2.7021	30.1	2.6868	38.2	2.6698	46.3	2.6582
5.9	2.7277	14	2.7223	22.1	2.7027	30.2	2.6862	38.3	2.671	46.4	2.6576
6	2.7296	14.1	2.7198	22.2	2.7021	30.3	2.6856	38.4	2.6691	46.5	2.6582
6.1	2.7296	14.2	2.721	22.3	2.7021	30.4	2.6832	38.5	2.6698	46.6	2.6588
6.2	2.7296	14.3	2.7223	22.4	2.7015	30.5	2.6838	38.6	2.6704	46.7	2.6563
6.3	2.7326	14.4	2.721	22.5	2.7003	30.6	2.6844	38.7	2.6698	46.8	2.6582
6.4	2.7314	14.5	2.7216	22.6	2.7027	30.7	2.6844	38.8	2.671	46.9	2.6576
6.5	2.732	14.6	2.721	22.7	2.6997	30.8	2.6838	38.9	2.6691	47	2.6576
6.6	2.7326	14.7	2.7216	22.8	2.7009	30.9	2.6838	39	2.6722	47.1	2.6557
6.7	2.7332	14.8	2.721	22.9	2.7003	31	2.6832	39.1	2.6691	47.2	2.6563
6.8	2.7332	14.9	2.7198	23	2.7003	31.1	2.6832	39.2	2.671	47.3	2.6557
6.9	2.732	15	2.7174	23.1	2.7003	31.2	2.6838	39.3	2.6704	47.4	2.6569
7	2.7332	15.1	2.7198	23.2	2.7003	31.3	2.6826	39.4	2.6698	47.5	2.6576
7.1	2.7332	15.2	2.7186	23.3	2.6997	31.4	2.6832	39.5	2.6698	47.6	2.6588
7.2	2.7338	15.3	2.7174	23.4	2.6978	31.5	2.6832	39.6	2.6691	47.7	2.6551
7.3	2.7345	15.4	2.7204	23.5	2.7003	31.6	2.682	39.7	2.6691	47.8	2.6582
7.4	2.7338	15.5	2.718	23.6	2.6978	31.7	2.6838	39.8	2.6685	47.9	2.6582
7.5	2.7351	15.6	2.7168	23.7	2.6997	31.8	2.6826	39.9	2.6691	48	2.6569
7.6	2.7338	15.7	2.7192	23.8	2.6991	31.9	2.6838	40	2.6698	48.1	2.6563
7.7	2.7314	15.8	2.718	23.9	2.6991	32	2.682	40.1	2.6685	48.2	2.6551
7.8	2.7308	15.9	2.718	24	2.6991	32.1	2.6814	40.2	2.6685	48.3	2.6563
7.9	2.7338	16	2.7186	24.1	2.6972	32.2	2.6826	40.3	2.6685	48.4	2.6551
8	2.7326	16.1	2.7149	24.2	2.6984	32.3	2.6795	40.4	2.6661	48.5	2.6551

Time (s)	Voltage (V)
48.6	2.6557
48.7	2.6539
48.8	2.6551
48.9	2.6557
49	2.6551
49.1	2.6557
49.2	2.6545
49.3	2.6545
49.4	2.6539
49.5	2.6539
49.6	2.6533
49.7	2.6539
49.8	2.6527
49.9	2.6533
50	2.6539
50.1	2.6527
50.2	2.6539
50.3	2.6514
50.4	2.6527
50.5	2.6508
50.6	2.6514
50.7	2.6521
50.8	2.6521
50.9	2.6527
51	2.6514
51.1	2.6502
51.2	2.6514
51.3	2.649
51.4	2.649
51.5	2.6502
51.6	2.6496
51.7	2.6484
51.8	2.6502
51.9	2.649
52	2.649
52.1	2.6484
52.2	2.6484
52.3	2.6496
52.4	2.6496
52.5	2.6466
52.6	2.6472
52.7	2.649
52.8	2.6484
52.9	2.646
53	2.6484
53.1	2.6484
53.2	2.649
53.3	2.6472
53.4	2.646
53.5	2.6478
53.6	2.6478
53.7	2.6466
53.8	2.6484
53.9	2.6466
54	2.6472
54.1	2.6453
54.2	2.6484
54.3	2.6453
54.4	2.6466
54.5	2.646
54.6	2.6453
54.7	2.6453
54.8	2.646
54.9	2.6447
55	2.6453
55.1	2.6441
55.2	2.646
55.3	2.646
55.4	2.6447
55.5	2.6435
55.6	2.6466
55.7	2.6399
55.8	2.6417
55.9	2.6441
56	2.6435
56.1	2.6411
56.2	2.6423
56.3	2.6429
56.4	2.6423
56.5	2.6429
56.6	2.6447

Time (s)	Voltage (V)
56.7	2.6411
56.8	2.6453
56.9	2.6447
57	2.6441
57.1	2.6435
57.2	2.6441
57.3	2.6423
57.4	2.6405
57.5	2.6441
57.6	2.6447
57.7	2.6429
57.8	2.6429
57.9	2.6423
58	2.6441
58.1	2.6441
58.2	2.6405
58.3	2.6435
58.4	2.6417
58.5	2.6405
58.6	2.6441
58.7	2.6411
58.8	2.6411
58.9	2.6435
59	2.6399
59.1	2.6386
59.2	2.6399
59.3	2.6392
59.4	2.6411
59.5	2.6405
59.6	2.6411
59.7	2.6411
59.8	2.6374
59.9	2.6399
60	2.6399

APPENDIX H.2

PARALLEL CONNECTION BETWEEN 330 MILIFARAD CAPACITANCE OF ULTRACAPACITOR WITH TWO MANGANESE BATTERIES

Time (s)	Voltage (V)	Time (s)	Voltage (V)	Time (s)	Voltage (V)	Time (s)	Voltage (V)	Time (s)	Voltage (V)	Time (s)	Voltage (V)
0	2.1711	8.1	2.7595	16.2	2.74	24.3	2.732	32.4	2.7155	40.5	2.7027
0.1	2.6917	8.2	2.7589	16.3	2.7412	24.4	2.732	32.5	2.7168	40.6	2.7046
0.2	2.7894	8.3	2.7607	16.4	2.7406	24.5	2.7314	32.6	2.7155	40.7	2.7015
0.3	2.7827	8.4	2.7607	16.5	2.7387	24.6	2.7308	32.7	2.7155	40.8	2.7009
0.4	2.7314	8.5	2.7631	16.6	2.74	24.7	2.7296	32.8	2.7161	40.9	2.7021
0.5	2.7528	8.6	2.7607	16.7	2.7393	24.8	2.7302	32.9	2.7155	41	2.7015
0.6	2.7802	8.7	2.7595	16.8	2.74	24.9	2.7302	33	2.7155	41.1	2.7015
0.7	2.7851	8.8	2.7338	16.9	2.74	25	2.7314	33.1	2.7155	41.2	2.7027
0.8	2.7912	8.9	2.7332	17	2.7393	25.1	2.7296	33.2	2.7161	41.3	2.7009
0.9	2.787	9	2.7332	17.1	2.74	25.2	2.7296	33.3	2.7149	41.4	2.7009
1	2.7949	9.1	2.7332	17.2	2.7393	25.3	2.7302	33.4	2.7131	41.5	2.7021
1.1	2.7937	9.2	2.7345	17.3	2.74	25.4	2.7296	33.5	2.7149	41.6	2.6997
1.2	2.7888	9.3	2.7375	17.4	2.7381	25.5	2.7284	33.6	2.7143	41.7	2.7015
1.3	2.7973	9.4	2.7351	17.5	2.7387	25.6	2.7271	33.7	2.7125	41.8	2.7015
1.4	2.7924	9.5	2.7369	17.6	2.7387	25.7	2.7271	33.8	2.7131	41.9	2.6997
1.5	2.79	9.6	2.7393	17.7	2.7387	25.8	2.7265	33.9	2.7131	42	2.7021
1.6	2.7918	9.7	2.74	17.8	2.7375	25.9	2.7265	34	2.7113	42.1	2.7003
1.7	2.7924	9.8	2.7375	17.9	2.7393	26	2.7265	34.1	2.7131	42.2	2.7015
1.8	2.7943	9.9	2.7406	18	2.7369	26.1	2.7253	34.2	2.7125	42.3	2.7003
1.9	2.7955	10	2.7412	18.1	2.7369	26.2	2.7253	34.3	2.7137	42.4	2.7015
2	2.7985	10.1	2.7418	18.2	2.7375	26.3	2.7253	34.4	2.7137	42.5	2.7009
2.1	2.7992	10.2	2.7424	18.3	2.74	26.4	2.7253	34.5	2.7131	42.6	2.7003
2.2	2.7967	10.3	2.7436	18.4	2.7387	26.5	2.7259	34.6	2.7149	42.7	2.6997
2.3	2.7979	10.4	2.7436	18.5	2.7387	26.6	2.7259	34.7	2.7131	42.8	2.7003
2.4	2.7979	10.5	2.7454	18.6	2.7381	26.7	2.7265	34.8	2.7149	42.9	2.6997
2.5	2.7961	10.6	2.7442	18.7	2.7381	26.8	2.7259	34.9	2.7137	43	2.7003
2.6	2.7937	10.7	2.7436	18.8	2.7369	26.9	2.7253	35	2.7137	43.1	2.6997
2.7	2.7931	10.8	2.7448	18.9	2.7381	27	2.7247	35.1	2.7125	43.2	2.6997
2.8	2.7943	10.9	2.7448	19	2.7381	27.1	2.7247	35.2	2.7131	43.3	2.7009
2.9	2.7931	11	2.7442	19.1	2.732	27.2	2.7271	35.3	2.7131	43.4	2.6997
3	2.787	11.1	2.7442	19.2	2.7363	27.3	2.7265	35.4	2.7125	43.5	2.6991
3.1	2.7894	11.2	2.7436	19.3	2.7381	27.4	2.7265	35.5	2.7113	43.6	2.7003
3.2	2.7827	11.3	2.7442	19.4	2.7375	27.5	2.7247	35.6	2.7113	43.7	2.6991
3.3	2.7906	11.4	2.7442	19.5	2.7375	27.6	2.7253	35.7	2.7131	43.8	2.6997
3.4	2.7882	11.5	2.7436	19.6	2.7369	27.7	2.7253	35.8	2.7131	43.9	2.6997
3.5	2.7876	11.6	2.743	19.7	2.7369	27.8	2.7235	35.9	2.7119	44	2.6997
3.6	2.787	11.7	2.7424	19.8	2.7387	27.9	2.7247	36	2.7107	44.1	2.6991
3.7	2.7863	11.8	2.7418	19.9	2.7363	28	2.7241	36.1	2.71	44.2	2.6997
3.8	2.7863	11.9	2.7424	20	2.7363	28.1	2.7241	36.2	2.7107	44.3	2.6997
3.9	2.7894	12	2.7424	20.1	2.7375	28.2	2.7235	36.3	2.7107	44.4	2.6984
4	2.7876	12.1	2.7424	20.2	2.7387	28.3	2.7235	36.4	2.7094	44.5	2.6978
4.1	2.7857	12.2	2.7412	20.3	2.7369	28.4	2.7235	36.5	2.7094	44.6	2.6984
4.2	2.787	12.3	2.7406	20.4	2.7393	28.5	2.7216	36.6	2.7094	44.7	2.6972
4.3	2.7851	12.4	2.74	20.5	2.7369	28.6	2.7216	36.7	2.71	44.8	2.6978
4.4	2.7857	12.5	2.7412	20.6	2.7375	28.7	2.7216	36.8	2.7088	44.9	2.6984
4.5	2.7863	12.6	2.74	20.7	2.7387	28.8	2.7223	36.9	2.7088	45	2.6966
4.6	2.7894	12.7	2.7406	20.8	2.7381	28.9	2.721	37	2.7082	45.1	2.6966
4.7	2.7863	12.8	2.7418	20.9	2.7381	29	2.7229	37.1	2.7076	45.2	2.6954
4.8	2.7863	12.9	2.7406	21	2.7387	29.1	2.721	37.2	2.7088	45.3	2.6966
4.9	2.7845	13	2.7406	21.1	2.7351	29.2	2.7216	37.3	2.7076	45.4	2.696
5	2.7839	13.1	2.7412	21.2	2.7345	29.3	2.721	37.4	2.7082	45.5	2.6966
5.1	2.7839	13.2	2.7418	21.3	2.7369	29.4	2.7204	37.5	2.7076	45.6	2.6972
5.2	2.7833	13.3	2.7418	21.4	2.7375	29.5	2.7216	37.6	2.7088	45.7	2.6954
5.3	2.7833	13.4	2.743	21.5	2.7369	29.6	2.7204	37.7	2.7088	45.8	2.696
5.4	2.7778	13.5	2.743	21.6	2.7375	29.7	2.7204	37.8	2.7082	45.9	2.6966
5.5	2.7815	13.6	2.7436	21.7	2.7351	29.8	2.7223	37.9	2.707	46	2.6978
5.6	2.7808	13.7	2.743	21.8	2.7351	29.9	2.7216	38	2.707	46.1	2.6966
5.7	2.7821	13.8	2.7436	21.9	2.7369	30	2.7216	38.1	2.7058	46.2	2.696
5.8	2.779	13.9	2.743	22	2.7351	30.1	2.7216	38.2	2.7064	46.3	2.696
5.9	2.776	14	2.7442	22.1	2.7363	30.2	2.721	38.3	2.7058	46.4	2.696
6	2.7772	14.1	2.7442	22.2	2.7345	30.3	2.7204	38.4	2.7046	46.5	2.696
6.1	2.7766	14.2	2.743	22.3	2.7332	30.4	2.721	38.5	2.7058	46.6	2.6954
6.2	2.7754	14.3	2.7424	22.4	2.7345	30.5	2.7198	38.6	2.7064	46.7	2.6948
6.3	2.7784	14.4	2.7418	22.5	2.7326	30.6	2.7204	38.7	2.7046	46.8	2.696
6.4	2.7772	14.5	2.7424	22.6	2.7345	30.7	2.7198	38.8	2.7058	46.9	2.696
6.5	2.7778	14.6	2.7418	22.7	2.7332	30.8	2.7198	38.9	2.7052	47	2.696
6.6	2.7754	14.7	2.7424	22.8	2.7314	30.9	2.7204	39	2.7058	47.1	2.6948
6.7	2.776	14.8	2.743	22.9	2.7351	31	2.7192	39.1	2.7046	47.2	2.696
6.8	2.7735	14.9	2.7418	23	2.7351	31.1	2.7186	39.2	2.7046	47.3	2.6954
6.9	2.7754	15	2.7424	23.1	2.7357	31.2	2.7192	39.3	2.7039	47.4	2.6948
7	2.7705	15.1	2.7424	23.2	2.732	31.3	2.7192	39.4	2.7033	47.5	2.6948
7.1	2.7711	15.2	2.7412	23.3	2.7314	31.4	2.7192	39.5	2.7039	47.6	2.6936
7.2	2.7705	15.3	2.7406	23.4	2.7314	31.5	2.7198	39.6	2.7052	47.7	2.6936
7.3	2.7711	15.4	2.7406	23.5	2.7357	31.6	2.7186	39.7	2.7039	47.8	2.6942
7.4	2.7699	15.5	2.7406	23.6	2.7357	31.7	2.718	39.8	2.7046	47.9	2.6948
7.5	2.7656	15.6	2.7393	23.7	2.7345	31.8	2.7168	39.9	2.7033	48	2.6942
7.6	2.7656	15.7	2.74	23.8	2.7351	31.9	2.7168	40	2.7027	48.1	2.6936
7.7	2.7638	15.8	2.7412	23.9	2.7326	32	2.7174	40.1	2.7027	48.2	2.6936
7.8	2.7631	15.9	2.7406	24	2.7332	32.1	2.7161	40.2	2.7027	48.3	2.6936
7.9	2.7644	16	2.7412	24.1	2.7326	32.2	2.7161	40.3	2.7039	48.4	2.6942
8	2.7601	16.1	2.7412	24.2	2.7314	32.3	2.7155	40.4	2.7046	48.5	2.6942

Time (s)	Voltage (V)
48.6	2.6936
48.7	2.6936
48.8	2.6948
48.9	2.6942
49	2.6936
49.1	2.693
49.2	2.6923
49.3	2.693
49.4	2.693
49.5	2.6923
49.6	2.6923
49.7	2.6923
49.8	2.6905
49.9	2.6911
50	2.6923
50.1	2.6905
50.2	2.6905
50.3	2.6911
50.4	2.6911
50.5	2.6911
50.6	2.6911
50.7	2.6893
50.8	2.6899
50.9	2.6905
51	2.6911
51.1	2.6887
51.2	2.6893
51.3	2.6899
51.4	2.6887
51.5	2.6887
51.6	2.6893
51.7	2.6899
51.8	2.6905
51.9	2.6893
52	2.6893
52.1	2.6899
52.2	2.6887
52.3	2.6868
52.4	2.6887
52.5	2.6881
52.6	2.6868
52.7	2.6868
52.8	2.6862
52.9	2.6868
53	2.6875
53.1	2.6856
53.2	2.6862
53.3	2.6868
53.4	2.6875
53.5	2.6862
53.6	2.685
53.7	2.6856
53.8	2.6862
53.9	2.685
54	2.685
54.1	2.6856
54.2	2.6838
54.3	2.685
54.4	2.6832
54.5	2.685
54.6	2.685
54.7	2.6844
54.8	2.6844
54.9	2.6862
55	2.6844
55.1	2.6856
55.2	2.6862
55.3	2.682
55.4	2.6838
55.5	2.682
55.6	2.685
55.7	2.6807
55.8	2.6844
55.9	2.682
56	2.6826
56.1	2.6826
56.2	2.6807
56.3	2.6826
56.4	2.6814
56.5	2.6826
56.6	2.682

Time (s)	Voltage (V)
56.7	2.682
56.8	2.682
56.9	2.682
57	2.682
57.1	2.6814
57.2	2.6807
57.3	2.6814
57.4	2.6814
57.5	2.6814
57.6	2.6814
57.7	2.6814
57.8	2.6807
57.9	2.6814
58	2.6814
58.1	2.6801
58.2	2.6807
58.3	2.6801
58.4	2.6801
58.5	2.6783
58.6	2.6807
58.7	2.6795
58.8	2.6795
58.9	2.6783
59	2.6783
59.1	2.6783
59.2	2.6783
59.3	2.6777
59.4	2.6759
59.5	2.6771
59.6	2.6783
59.7	2.6771
59.8	2.6777
59.9	2.6765
60	2.6765

APPENDIX H.3

PARALLEL CONNECTION BETWEEN 1000 MILIFARAD CAPACITANCE OF ULTRACAPACITOR WITH TWO MANGANESE BATTERIES

Time (s)	Voltage (V)	Time (s)	Voltage (V)	Time (s)	Voltage (V)	Time (s)	Voltage (V)	Time (s)	Voltage (V)	Time (s)	Voltage (V)
0	2.7033	8.1	2.9255	16.2	2.8986	24.3	2.8767	32.4	2.859	40.5	2.8455
0.1	2.8871	8.2	2.9261	16.3	2.8993	24.4	2.8767	32.5	2.859	40.6	2.8443
0.2	2.9347	8.3	2.9255	16.4	2.8993	24.5	2.8767	32.6	2.8584	40.7	2.8425
0.3	2.9542	8.4	2.9237	16.5	2.8986	24.6	2.8748	32.7	2.859	40.8	2.8419
0.4	2.9621	8.5	2.9237	16.6	2.8974	24.7	2.8755	32.8	2.8584	40.9	2.8431
0.5	2.9664	8.6	2.9255	16.7	2.8962	24.8	2.8742	32.9	2.8584	41	2.8425
0.6	2.9652	8.7	2.9237	16.8	2.8956	24.9	2.8767	33	2.8584	41.1	2.8419
0.7	2.9658	8.8	2.9231	16.9	2.898	25	2.8742	33.1	2.8578	41.2	2.8419
0.8	2.9646	8.9	2.9212	17	2.8968	25.1	2.8761	33.2	2.8578	41.3	2.8419
0.9	2.9633	9	2.9225	17.1	2.8968	25.2	2.8755	33.3	2.8578	41.4	2.8419
1	2.9633	9.1	2.9243	17.2	2.8968	25.3	2.8748	33.4	2.8571	41.5	2.8431
1.1	2.964	9.2	2.9225	17.3	2.8944	25.4	2.8742	33.5	2.8553	41.6	2.8407
1.2	2.9627	9.3	2.9212	17.4	2.8944	25.5	2.8748	33.6	2.8584	41.7	2.8413
1.3	2.9615	9.4	2.92	17.5	2.895	25.6	2.873	33.7	2.8584	41.8	2.8407
1.4	2.9609	9.5	2.9206	17.6	2.8944	25.7	2.873	33.8	2.8578	41.9	2.8382
1.5	2.9609	9.6	2.92	17.7	2.8932	25.8	2.8742	33.9	2.8571	42	2.8401
1.6	2.9603	9.7	2.9182	17.8	2.8932	25.9	2.873	34	2.8547	42.1	2.8401
1.7	2.9591	9.8	2.92	17.9	2.8944	26	2.8736	34.1	2.8553	42.2	2.8419
1.8	2.9591	9.9	2.9194	18	2.8938	26.1	2.873	34.2	2.8571	42.3	2.8394
1.9	2.9585	10	2.9163	18.1	2.8932	26.2	2.8724	34.3	2.8559	42.4	2.8407
2	2.9566	10.1	2.9182	18.2	2.8925	26.3	2.8736	34.4	2.8571	42.5	2.8382
2.1	2.956	10.2	2.9194	18.3	2.8925	26.4	2.8724	34.5	2.8529	42.6	2.8401
2.2	2.956	10.3	2.9157	18.4	2.8925	26.5	2.8712	34.6	2.8547	42.7	2.8394
2.3	2.956	10.4	2.917	18.5	2.8913	26.6	2.8718	34.7	2.8547	42.8	2.8407
2.4	2.956	10.5	2.9176	18.6	2.8919	26.7	2.8724	34.8	2.8559	42.9	2.8394
2.5	2.953	10.6	2.9163	18.7	2.8925	26.8	2.8724	34.9	2.8535	43	2.8394
2.6	2.953	10.7	2.917	18.8	2.8919	26.9	2.8718	35	2.8553	43.1	2.8382
2.7	2.9542	10.8	2.9151	18.9	2.8901	27	2.8706	35.1	2.8529	43.2	2.8401
2.8	2.9524	10.9	2.9145	19	2.8913	27.1	2.8718	35.2	2.8541	43.3	2.8382
2.9	2.9518	11	2.9163	19.1	2.8913	27.2	2.8694	35.3	2.8523	43.4	2.8388
3	2.9524	11.1	2.9151	19.2	2.8901	27.3	2.87	35.4	2.8541	43.5	2.8394
3.1	2.9505	11.2	2.9145	19.3	2.8901	27.4	2.87	35.5	2.8535	43.6	2.8376
3.2	2.9493	11.3	2.9133	19.4	2.8919	27.5	2.87	35.6	2.8535	43.7	2.8388
3.3	2.9493	11.4	2.9127	19.5	2.8907	27.6	2.8687	35.7	2.8535	43.8	2.8382
3.4	2.9493	11.5	2.9121	19.6	2.8889	27.7	2.8681	35.8	2.8523	43.9	2.837
3.5	2.9487	11.6	2.9115	19.7	2.8901	27.8	2.8675	35.9	2.8529	44	2.8382
3.6	2.9475	11.7	2.9121	19.8	2.8895	27.9	2.8669	36	2.8529	44.1	2.8382
3.7	2.9469	11.8	2.9139	19.9	2.8889	28	2.8681	36.1	2.8504	44.2	2.8358
3.8	2.9463	11.9	2.9115	20	2.8864	28.1	2.8681	36.2	2.8529	44.3	2.8358
3.9	2.9469	12	2.9121	20.1	2.8871	28.2	2.8687	36.3	2.851	44.4	2.8376
4	2.9463	12.1	2.9121	20.2	2.8877	28.3	2.8694	36.4	2.8516	44.5	2.8364
4.1	2.9456	12.2	2.9109	20.3	2.8864	28.4	2.8669	36.5	2.851	44.6	2.8358
4.2	2.9438	12.3	2.9109	20.4	2.8877	28.5	2.8675	36.6	2.851	44.7	2.8364
4.3	2.945	12.4	2.909	20.5	2.8852	28.6	2.8675	36.7	2.8504	44.8	2.8346
4.4	2.9432	12.5	2.9096	20.6	2.8889	28.7	2.8675	36.8	2.851	44.9	2.837
4.5	2.942	12.6	2.909	20.7	2.8858	28.8	2.8669	36.9	2.851	45	2.8358
4.6	2.9426	12.7	2.9072	20.8	2.8852	28.9	2.8663	37	2.8498	45.1	2.837
4.7	2.9426	12.8	2.9096	20.9	2.8834	29	2.8669	37.1	2.8498	45.2	2.8339
4.8	2.9414	12.9	2.9084	21	2.8852	29.1	2.8663	37.2	2.8504	45.3	2.8339
4.9	2.9426	13	2.9096	21.1	2.8871	29.2	2.8651	37.3	2.8492	45.4	2.8358
5	2.9402	13.1	2.9084	21.2	2.884	29.3	2.8651	37.4	2.8504	45.5	2.8339
5.1	2.9402	13.2	2.9072	21.3	2.8852	29.4	2.8657	37.5	2.8486	45.6	2.8346
5.2	2.9389	13.3	2.9066	21.4	2.8834	29.5	2.8632	37.6	2.8504	45.7	2.8352
5.3	2.9402	13.4	2.906	21.5	2.8834	29.6	2.8651	37.7	2.848	45.8	2.8346
5.4	2.9359	13.5	2.906	21.6	2.8834	29.7	2.8663	37.8	2.8492	45.9	2.8352
5.5	2.9383	13.6	2.9066	21.7	2.8828	29.8	2.8639	37.9	2.848	46	2.8352
5.6	2.9365	13.7	2.906	21.8	2.8828	29.9	2.8651	38	2.8492	46.1	2.8346
5.7	2.9377	13.8	2.906	21.9	2.8846	30	2.8632	38.1	2.8486	46.2	2.8339
5.8	2.9377	13.9	2.9066	22	2.8822	30.1	2.8639	38.2	2.848	46.3	2.8346
5.9	2.9347	14	2.9048	22.1	2.8809	30.2	2.8632	38.3	2.8468	46.4	2.8346
6	2.9353	14.1	2.9048	22.2	2.8816	30.3	2.8645	38.4	2.8468	46.5	2.8327
6.1	2.9347	14.2	2.906	22.3	2.8809	30.4	2.8632	38.5	2.8474	46.6	2.8315
6.2	2.9347	14.3	2.9041	22.4	2.8803	30.5	2.8639	38.6	2.8468	46.7	2.8333
6.3	2.934	14.4	2.9041	22.5	2.8791	30.6	2.8632	38.7	2.8474	46.8	2.8321
6.4	2.934	14.5	2.9029	22.6	2.8816	30.7	2.8626	38.8	2.848	46.9	2.8327
6.5	2.9334	14.6	2.9041	22.7	2.8809	30.8	2.8626	38.9	2.8462	47	2.8339
6.6	2.9322	14.7	2.9017	22.8	2.8803	30.9	2.8608	39	2.8449	47.1	2.8333
6.7	2.9334	14.8	2.9029	22.9	2.8816	31	2.862	39.1	2.8462	47.2	2.8339
6.8	2.9316	14.9	2.9035	23	2.8791	31.1	2.8626	39.2	2.8443	47.3	2.8321
6.9	2.9316	15	2.9023	23.1	2.8797	31.2	2.862	39.3	2.8468	47.4	2.8321
7	2.931	15.1	2.9017	23.2	2.8791	31.3	2.8602	39.4	2.8449	47.5	2.8309
7.1	2.931	15.2	2.9023	23.3	2.8791	31.4	2.8608	39.5	2.8449	47.6	2.8309
7.2	2.931	15.3	2.9017	23.4	2.8791	31.5	2.8602	39.6	2.8455	47.7	2.8303
7.3	2.9292	15.4	2.9029	23.5	2.8797	31.6	2.8626	39.7	2.8455	47.8	2.8327
7.4	2.931	15.5	2.8993	23.6	2.8791	31.7	2.8602	39.8	2.8455	47.9	2.8315
7.5	2.9279	15.6	2.8993	23.7	2.8785	31.8	2.8596	39.9	2.8449	48	2.8309
7.6	2.9292	15.7	2.8993	23.8	2.8779	31.9	2.8608	40	2.8437	48.1	2.8297
7.7	2.9279	15.8	2.9005	23.9	2.8773	32	2.8596	40.1	2.8431	48.2	2.8309
7.8	2.9273	15.9	2.8999	24	2.8767	32.1	2.859	40.2	2.8443	48.3	2.8303
7.9	2.9261	16	2.8999	24.1	2.8773	32.2	2.8602	40.3	2.8443	48.4	2.8309
8	2.9261	16.1	2.898	24.2	2.8767	32.3	2.8596	40.4	2.8431	48.5	2.8297

Time (s)	Voltage (V)
48.6	2.8291
48.7	2.8285
48.8	2.8309
48.9	2.8303
49	2.8297
49.1	2.8309
49.2	2.8291
49.3	2.8291
49.4	2.8291
49.5	2.8291
49.6	2.8278
49.7	2.8297
49.8	2.8266
49.9	2.8272
50	2.8291
50.1	2.8278
50.2	2.8266
50.3	2.8272
50.4	2.8266
50.5	2.826
50.6	2.8272
50.7	2.8272
50.8	2.826
50.9	2.8266
51	2.8254
51.1	2.8266
51.2	2.826
51.3	2.826
51.4	2.8254
51.5	2.8248
51.6	2.8248
51.7	2.826
51.8	2.8254
51.9	2.8248
52	2.8254
52.1	2.8254
52.2	2.8254
52.3	2.8242
52.4	2.8242
52.5	2.823
52.6	2.8254
52.7	2.8248
52.8	2.823
52.9	2.8236
53	2.826
53.1	2.8254
53.2	2.823
53.3	2.823
53.4	2.823
53.5	2.8248
53.6	2.823
53.7	2.8236
53.8	2.8217
53.9	2.823
54	2.8217
54.1	2.8217
54.2	2.8211
54.3	2.8211
54.4	2.8205
54.5	2.8211
54.6	2.8205
54.7	2.8205
54.8	2.8205
54.9	2.8193
55	2.8181
55.1	2.8187
55.2	2.8205
55.3	2.8193
55.4	2.8199
55.5	2.8193
55.6	2.8193
55.7	2.8181
55.8	2.8187
55.9	2.8187
56	2.8224
56.1	2.8193
56.2	2.8181
56.3	2.8193
56.4	2.8193
56.5	2.8181
56.6	2.8193

Time (s)	Voltage (V)
56.7	2.8169
56.8	2.8187
56.9	2.8193
57	2.8169
57.1	2.8162
57.2	2.8169
57.3	2.815
57.4	2.8169
57.5	2.8156
57.6	2.8175
57.7	2.8156
57.8	2.8162
57.9	2.815
58	2.8169
58.1	2.8156
58.2	2.8156
58.3	2.815
58.4	2.8156
58.5	2.8162
58.6	2.8169
58.7	2.8156
58.8	2.815
58.9	2.815
59	2.8144
59.1	2.8138
59.2	2.8138
59.3	2.8156
59.4	2.8138
59.5	2.8132
59.6	2.815
59.7	2.8144
59.8	2.8144
59.9	2.8126
60	2.8132

APPENDIX H.4

PARALLEL CONNECTION BETWEEN 1500 MILIFARAD CAPACITANCE OF ULTRACAPACITOR WITH TWO MANGANESE BATTERIES

Time (s)	Voltage (V)	Time (s)	Voltage (V)	Time (s)	Voltage (V)	Time (s)	Voltage (V)	Time (s)	Voltage (V)	Time (s)	Voltage (V)
0	2.3518	8.1	2.3835	16.2	2.3841	24.3	2.3707	32.4	2.284	40.5	2.3029
0.1	2.3316	8.2	2.3792	16.3	2.3829	24.4	2.3701	32.5	2.2913	40.6	2.2944
0.2	2.3542	8.3	2.3817	16.4	2.3841	24.5	2.3688	32.6	2.3157	40.7	2.2913
0.3	2.3627	8.4	2.3835	16.5	2.3792	24.6	2.3682	32.7	2.3298	40.8	2.2846
0.4	2.4207	8.5	2.3804	16.6	2.3676	24.7	2.3688	32.8	2.3243	40.9	2.3139
0.5	2.4348	8.6	2.3774	16.7	2.364	24.8	2.3688	32.9	2.3249	41	2.298
0.6	2.4293	8.7	2.3804	16.8	2.3341	24.9	2.3676	33	2.3249	41.1	2.3121
0.7	2.4036	8.8	2.3872	16.9	2.3695	25	2.3707	33.1	2.3041	41.2	2.3066
0.8	2.4622	8.9	2.389	17	2.375	25.1	2.3688	33.2	2.3139	41.3	2.2633
0.9	2.425	9	2.3841	17.1	2.3774	25.2	2.3627	33.3	2.306	41.4	2.2767
1	2.4537	9.1	2.3847	17.2	2.3792	25.3	2.3603	33.4	2.3133	41.5	2.2956
1.1	2.4567	9.2	2.3841	17.3	2.3798	25.4	2.3572	33.5	2.3054	41.6	2.2987
1.2	2.4683	9.3	2.3798	17.4	2.3811	25.5	2.3554	33.6	2.273	41.7	2.2932
1.3	2.4598	9.4	2.3713	17.5	2.3823	25.6	2.3591	33.7	2.2938	41.8	2.248
1.4	2.4494	9.5	2.3713	17.6	2.3811	25.7	2.3572	33.8	2.3096	41.9	2.306
1.5	2.4421	9.6	2.3701	17.7	2.3829	25.8	2.3566	33.9	2.3145	42	2.3066
1.6	2.4415	9.7	2.3444	17.8	2.3829	25.9	2.3566	34	2.3096	42.1	2.2907
1.7	2.4329	9.8	2.3444	17.9	2.3835	26	2.3542	34.1	2.3115	42.2	2.2773
1.8	2.4506	9.9	2.3664	18	2.3841	26.1	2.3542	34.2	2.3157	42.3	2.3157
1.9	2.4433	10	2.3493	18.1	2.3835	26.2	2.3518	34.3	2.3103	42.4	2.3139
2	2.4439	10.1	2.3298	18.2	2.3847	26.3	2.3432	34.4	2.3084	42.5	2.2755
2.1	2.4494	10.2	2.3054	18.3	2.3829	26.4	2.3402	34.5	2.306	42.6	2.2919
2.2	2.414	10.3	2.3695	18.4	2.3823	26.5	2.3341	34.6	2.2907	42.7	2.273
2.3	2.4299	10.4	2.3597	18.5	2.3817	26.6	2.3225	34.7	2.2425	42.8	2.2993
2.4	2.425	10.5	2.364	18.6	2.3798	26.7	2.298	34.8	2.3078	42.9	2.3054
2.5	2.4213	10.6	2.3554	18.7	2.3792	26.8	2.3328	34.9	2.2993	43	2.3109
2.6	2.4146	10.7	2.32	18.8	2.3792	26.9	2.3347	35	2.2651	43.1	2.3188
2.7	2.4067	10.8	2.3359	18.9	2.3786	27	2.3164	35.1	2.3115	43.2	2.3206
2.8	2.4067	10.9	2.3524	19	2.378	27.1	2.295	35.2	2.3188	43.3	2.317
2.9	2.4201	11	2.3615	19.1	2.3804	27.2	2.3402	35.3	2.3194	43.4	2.3212
3	2.4219	11.1	2.3444	19.2	2.3798	27.3	2.3444	35.4	2.3145	43.5	2.3157
3.1	2.414	11.2	2.309	19.3	2.3786	27.4	2.3493	35.5	2.3115	43.6	2.3084
3.2	2.389	11.3	2.3713	19.4	2.378	27.5	2.353	35.6	2.3023	43.7	2.2938
3.3	2.4073	11.4	2.3603	19.5	2.3768	27.6	2.3566	35.7	2.2767	43.8	2.2871
3.4	2.4073	11.5	2.3505	19.6	2.3725	27.7	2.3585	35.8	2.309	43.9	2.2913
3.5	2.4036	11.6	2.3707	19.7	2.3701	27.8	2.3524	35.9	2.3011	44	2.2858
3.6	2.3981	11.7	2.3145	19.8	2.367	27.9	2.3487	36	2.3194	44.1	2.3255
3.7	2.3994	11.8	2.3103	19.9	2.3719	28	2.3481	36.1	2.3151	44.2	2.3286
3.8	2.4024	11.9	2.3408	20	2.3743	28.1	2.3499	36.2	2.3341	44.3	2.3273
3.9	2.3884	12	2.3823	20.1	2.3695	28.2	2.3493	36.3	2.331	44.4	2.3328
4	2.3957	12.1	2.3811	20.2	2.3676	28.3	2.3499	36.4	2.3255	44.5	2.3353
4.1	2.4006	12.2	2.3756	20.3	2.3658	28.4	2.3487	36.5	2.3249	44.6	2.3334
4.2	2.4024	12.3	2.3695	20.4	2.3627	28.5	2.3475	36.6	2.3139	44.7	2.3334
4.3	2.3945	12.4	2.3566	20.5	2.3634	28.6	2.3481	36.7	2.3164	44.8	2.3316
4.4	2.4018	12.5	2.353	20.6	2.3579	28.7	2.3469	36.8	2.3243	44.9	2.3341
4.5	2.3914	12.6	2.3609	20.7	2.3505	28.8	2.3493	36.9	2.2993	45	2.3316
4.6	2.4018	12.7	2.353	20.8	2.3475	28.9	2.345	37	2.32	45.1	2.3341
4.7	2.3835	12.8	2.3548	20.9	2.32	29	2.342	37.1	2.298	45.2	2.3383
4.8	2.3914	12.9	2.3371	21	2.3212	29.1	2.3334	37.2	2.2761	45.3	2.3334
4.9	2.3939	13	2.3499	21.1	2.3554	29.2	2.3066	37.3	2.3151	45.4	2.3322
5	2.3981	13.1	2.3646	21.2	2.364	29.3	2.3237	37.4	2.3157	45.5	2.3267
5.1	2.4024	13.2	2.3646	21.3	2.3682	29.4	2.3249	37.5	2.3133	45.6	2.3267
5.2	2.3951	13.3	2.3286	21.4	2.3682	29.5	2.3115	37.6	2.273	45.7	2.331
5.3	2.3969	13.4	2.3627	21.5	2.3707	29.6	2.2767	37.7	2.3164	45.8	2.3261
5.4	2.3914	13.5	2.3499	21.6	2.3725	29.7	2.3273	37.8	2.2871	45.9	2.3157
5.5	2.3896	13.6	2.3713	21.7	2.3719	29.8	2.328	37.9	2.3151	46	2.3145
5.6	2.389	13.7	2.3646	21.8	2.3725	29.9	2.331	38	2.3188	46.1	2.2956
5.7	2.3914	13.8	2.3402	21.9	2.3731	30	2.3273	38.1	2.2993	46.2	2.3035
5.8	2.3896	13.9	2.3615	22	2.3731	30.1	2.2944	38.2	2.32	46.3	2.3182
5.9	2.3902	14	2.3267	22.1	2.3731	30.2	2.3164	38.3	2.3292	46.4	2.3151
6	2.3884	14.1	2.3792	22.2	2.3731	30.3	2.3255	38.4	2.3267	46.5	2.3151
6.1	2.3768	14.2	2.3817	22.3	2.3731	30.4	2.3023	38.5	2.3292	46.6	2.309
6.2	2.3743	14.3	2.3829	22.4	2.3719	30.5	2.3115	38.6	2.3231	46.7	2.2907
6.3	2.3682	14.4	2.389	22.5	2.375	30.6	2.2987	38.7	2.3157	46.8	2.3048
6.4	2.3725	14.5	2.3914	22.6	2.3737	30.7	2.2626	38.8	2.3072	46.9	2.298
6.5	2.3835	14.6	2.3914	22.7	2.3737	30.8	2.3084	38.9	2.2645	47	2.3035
6.6	2.3859	14.7	2.3927	22.8	2.3725	30.9	2.2852	39	2.3054	47.1	2.284
6.7	2.3884	14.8	2.3914	22.9	2.3719	31	2.3292	39.1	2.3145	47.2	2.2675
6.8	2.3872	14.9	2.3927	23	2.3737	31.1	2.3414	39.2	2.3261	47.3	2.2456
6.9	2.3847	15	2.3927	23.1	2.3743	31.2	2.3383	39.3	2.3322	47.4	2.3072
7	2.3847	15.1	2.3933	23.2	2.3713	31.3	2.3365	39.4	2.3286	47.5	2.3133
7.1	2.3817	15.2	2.3939	23.3	2.3743	31.4	2.3359	39.5	2.3298	47.6	2.3218
7.2	2.3774	15.3	2.3914	23.4	2.3737	31.5	2.3341	39.6	2.3237	47.7	2.32
7.3	2.3774	15.4	2.3908	23.5	2.3731	31.6	2.3389	39.7	2.3212	47.8	2.32
7.4	2.3811	15.5	2.3908	23.6	2.3701	31.7	2.3341	39.8	2.3115	47.9	2.3188
7.5	2.3817	15.6	2.3908	23.7	2.3719	31.8	2.3322	39.9	2.3066	48	2.3194
7.6	2.3859	15.7	2.3908	23.8	2.3725	31.9	2.3273	40	2.3133	48.1	2.3157
7.7	2.3817	15.8	2.3902	23.9	2.3719	32	2.3267	40.1	2.3139	48.2	2.3078
7.8	2.3768	15.9	2.3902	24	2.3719	32.1	2.2956	40.2	2.3084	48.3	2.2913
7.9	2.3829	16	2.3884	24.1	2.3719	32.2	2.2748	40.3	2.2736	48.4	2.3109
8	2.3872	16.1	2.3872	24.2	2.3707	32.3	2.3109	40.4	2.3121	48.5	2.3109

Time (s)	Voltage (V)
48.6	2.306
48.7	2.2938
48.8	2.2462
48.9	2.2492
49	2.2962
49.1	2.251
49.2	2.284
49.3	2.273
49.4	2.3017
49.5	2.3017
49.6	2.2846
49.7	2.2864
49.8	2.2669
49.9	2.2816
50	2.2846
50.1	2.298
50.2	2.262
50.3	2.2834
50.4	2.2761
50.5	2.2474
50.6	2.2675
50.7	2.2279
50.8	2.2803
50.9	2.2462
51	2.2864
51.1	2.2871
51.2	2.2559
51.3	2.3066
51.4	2.3072
51.5	2.3035
51.6	2.2883
51.7	2.2761
51.8	2.2828
51.9	2.2852
52	2.2858
52.1	2.3048
52.2	2.3084
52.3	2.3041
52.4	2.2645
52.5	2.3054
52.6	2.3084
52.7	2.2816
52.8	2.306
52.9	2.3188
53	2.3225
53.1	2.3255
53.2	2.3261
53.3	2.3292
53.4	2.328
53.5	2.3286
53.6	2.3286
53.7	2.3218
53.8	2.3212
53.9	2.3218
54	2.3206
54.1	2.3212
54.2	2.3212
54.3	2.32
54.4	2.32
54.5	2.3194
54.6	2.32
54.7	2.3212
54.8	2.3194
54.9	2.3194
55	2.3206
55.1	2.32
55.2	2.317
55.3	2.3157
55.4	2.3145
55.5	2.3139
55.6	2.3188
55.7	2.3182
55.8	2.3231
55.9	2.3292
56	2.3304
56.1	2.3304
56.2	2.3261
56.3	2.3298
56.4	2.3273
56.5	2.3188
56.6	2.3017

Time (s)	Voltage (V)
56.7	2.2932
56.8	2.3072
56.9	2.3066
57	2.306
57.1	2.3035
57.2	2.3066
57.3	2.306
57.4	2.3048
57.5	2.3005
57.6	2.2907
57.7	2.2712
57.8	2.2504
57.9	2.2541
58	2.2547
58.1	2.2431
58.2	2.3017
58.3	2.3103
58.4	2.3164
58.5	2.317
58.6	2.3164
58.7	2.3157
58.8	2.3139
58.9	2.3109
59	2.3109
59.1	2.3109
59.2	2.3145
59.3	2.3127
59.4	2.3115
59.5	2.3115
59.6	2.3084
59.7	2.3023
59.8	2.3048
59.9	2.3072
60	2.3066

APPENDIX H.5

PARALLEL CONNECTION BETWEEN 22000 MILIFARAD CAPACITANCE OF ULTRACAPACITOR WITH TWO MANGANESE BATTERIES

Time (s)	Voltage (V)
0	2.5312
0.1	2.4403
0.2	2.4738
0.3	2.4812
0.4	2.4842
0.5	2.4647
0.6	2.4537
0.7	2.45
0.8	2.4445
0.9	2.4384
1	2.4342
1.1	2.4274
1.2	2.4232
1.3	2.4244
1.4	2.4165
1.5	2.4195
1.6	2.4207
1.7	2.4207
1.8	2.4274
1.9	2.4146
2	2.3896
2.1	2.3835
2.2	2.3988
2.3	2.4067
2.4	2.4049
2.5	2.483
2.6	2.5001
2.7	2.497
2.8	2.5117
2.9	2.5275
3	2.5208
3.1	2.5251
3.2	2.5202
3.3	2.5135
3.4	2.5202
3.5	2.5233
3.6	2.5379
3.7	2.5385
3.8	2.5391
3.9	2.5422
4	2.5477
4.1	2.5501
4.2	2.5501
4.3	2.5507
4.4	2.555
4.5	2.5544
4.6	2.5526
4.7	2.5575
4.8	2.5581
4.9	2.5611
5	2.5611
5.1	2.5654
5.2	2.5654
5.3	2.5636
5.4	2.5648
5.5	2.5636
5.6	2.566
5.7	2.5752
5.8	2.5678
5.9	2.5672
6	2.5648
6.1	2.5642
6.2	2.5642
6.3	2.5642
6.4	2.5648
6.5	2.5629
6.6	2.566
6.7	2.5678
6.8	2.569
6.9	2.566
7	2.5648
7.1	2.5672
7.2	2.5666
7.3	2.5672
7.4	2.5636
7.5	2.5684
7.6	2.5654
7.7	2.5642
7.8	2.566
7.9	2.5648
8	2.5654

Time (s)	Voltage (V)
8.1	2.5636
8.2	2.5623
8.3	2.5623
8.4	2.5648
8.5	2.5648
8.6	2.566
8.7	2.5636
8.8	2.5654
8.9	2.5648
9	2.5648
9.1	2.5654
9.2	2.566
9.3	2.566
9.4	2.5666
9.5	2.5654
9.6	2.5642
9.7	2.5636
9.8	2.5642
9.9	2.5672
10	2.5629
10.1	2.566
10.2	2.5642
10.3	2.5623
10.4	2.5623
10.5	2.5599
10.6	2.5611
10.7	2.5629
10.8	2.5642
10.9	2.5636
11	2.566
11.1	2.5629
11.2	2.5636
11.3	2.5629
11.4	2.5629
11.5	2.5636
11.6	2.5642
11.7	2.5642
11.8	2.5672
11.9	2.566
12	2.5672
12.1	2.5672
12.2	2.5654
12.3	2.5636
12.4	2.5636
12.5	2.5648
12.6	2.5648
12.7	2.5648
12.8	2.5648
12.9	2.5629
13	2.5648
13.1	2.5629
13.2	2.5642
13.3	2.5629
13.4	2.5648
13.5	2.5642
13.6	2.5636
13.7	2.5654
13.8	2.5654
13.9	2.5672
14	2.5648
14.1	2.566
14.2	2.566
14.3	2.5648
14.4	2.5629
14.5	2.5636
14.6	2.5642
14.7	2.5617
14.8	2.5636
14.9	2.5623
15	2.5617
15.1	2.5642
15.2	2.5623
15.3	2.5636
15.4	2.5642
15.5	2.5654
15.6	2.5636
15.7	2.5642
15.8	2.5648
15.9	2.5648
16	2.5617
16.1	2.5636

Time (s)	Voltage (V)
16.2	2.5648
16.3	2.566
16.4	2.5623
16.5	2.5642
16.6	2.5623
16.7	2.5623
16.8	2.5636
16.9	2.5623
17	2.5636
17.1	2.5629
17.2	2.5617
17.3	2.5617
17.4	2.5617
17.5	2.5623
17.6	2.5623
17.7	2.5629
17.8	2.5629
17.9	2.5617
18	2.5617
18.1	2.5623
18.2	2.5611
18.3	2.5617
18.4	2.5617
18.5	2.5617
18.6	2.5623
18.7	2.5617
18.8	2.5611
18.9	2.5611
19	2.5611
19.1	2.5623
19.2	2.5593
19.3	2.5599
19.4	2.5599
19.5	2.5617
19.6	2.5611
19.7	2.5629
19.8	2.5629
19.9	2.5611
20	2.5611
20.1	2.5611
20.2	2.5611
20.3	2.5611
20.4	2.5605
20.5	2.5587
20.6	2.5587
20.7	2.5599
20.8	2.5605
20.9	2.5599
21	2.5581
21.1	2.5593
21.2	2.5617
21.3	2.5617
21.4	2.5623
21.5	2.5575
21.6	2.5599
21.7	2.5611
21.8	2.5581
21.9	2.5593
22	2.5575
22.1	2.5623
22.2	2.5593
22.3	2.5587
22.4	2.5581
22.5	2.5575
22.6	2.5587
22.7	2.5617
22.8	2.5611
22.9	2.5575
23	2.5568
23.1	2.5581
23.2	2.5587
23.3	2.5581
23.4	2.5575
23.5	2.5599
23.6	2.5581
23.7	2.5605
23.8	2.5575
23.9	2.5617
24	2.5599
24.1	2.5587
24.2	2.5587

Time (s)	Voltage (V)
24.3	2.5568
24.4	2.5575
24.5	2.5568
24.6	2.5593
24.7	2.5593
24.8	2.5568
24.9	2.5605
25	2.5587
25.1	2.5581
25.2	2.5581
25.3	2.5587
25.4	2.5575
25.5	2.5562
25.6	2.5593
25.7	2.5581
25.8	2.5568
25.9	2.5568
26	2.5581
26.1	2.5568
26.2	2.5575
26.3	2.5593
26.4	2.5575
26.5	2.5575
26.6	2.5617
26.7	2.5581
26.8	2.5568
26.9	2.5575
27	2.5575
27.1	2.555
27.2	2.5544
27.3	2.5562
27.4	2.5568
27.5	2.5568
27.6	2.5568
27.7	2.555
27.8	2.5587
27.9	2.5562
28	2.5581
28.1	2.555
28.2	2.5556
28.3	2.5556
28.4	2.555
28.5	2.5568
28.6	2.5562
28.7	2.5544
28.8	2.555
28.9	2.5575
29	2.5575
29.1	2.555
29.2	2.5544
29.3	2.5562
29.4	2.555
29.5	2.5556
29.6	2.5562
29.7	2.5556
29.8	2.5556
29.9	2.5556
30	2.5562
30.1	2.5581
30.2	2.5568
30.3	2.5562
30.4	2.5575
30.5	2.5562
30.6	2.5556
30.7	2.5562
30.8	2.555
30.9	2.5568
31	2.5556
31.1	2.5556
31.2	2.5568
31.3	2.555
31.4	2.555
31.5	2.5568
31.6	2.5556
31.7	2.5562
31.8	2.5544
31.9	2.5562
32	2.5556
32.1	2.5556
32.2	2.5538
32.3	2.5544

Time (s)	Voltage (V)
32.4	2.5538
32.5	2.555
32.6	2.5538
32.7	2.5544
32.8	2.5538
32.9	2.5526
33	2.5544
33.1	2.5556
33.2	2.5544
33.3	2.555
33.4	2.5562
33.5	2.5556
33.6	2.5544
33.7	2.5507
33.8	2.5495
33.9	2.5501
34	2.552
34.1	2.5532
34.2	2.5513
34.3	2.5495
34.4	2.552
34.5	2.5507
34.6	2.5507
34.7	2.552
34.8	2.5501
34.9	2.5495
35	2.552
35.1	2.5513
35.2	2.5495
35.3	2.552
35.4	2.5513
35.5	2.5501
35.6	2.5501
35.7	2.5501
35.8	2.5507
35.9	2.5501
36	2.5507
36.1	2.5501
36.2	2.5507
36.3	2.5501
36.4	2.5513
36.5	2.5507
36.6	2.552
36.7	2.5507
36.8	2.5507
36.9	2.5507
37	2.5513
37.1	2.5513
37.2	2.5495
37.3	2.5513
37.4	2.5532
37.5	2.5501
37.6	2.5526
37.7	2.5532
37.8	2.5526
37.9	2.5483
38	2.5489
38.1	2.5495
38.2	2.5513
38.3	2.5507
38.4	2.5501
38.5	2.5507
38.6	2.5526
38.7	2.5507
38.8	2.5507
38.9	2.5501
39	2.5532
39.1	2.5513
39.2	2.5532
39.3	2.5495
39.4	2.5489
39.5	2.5526
39.6	2.5507
39.7	2.5507
39.8	2.5526
39.9	2.5489
40	2.5501
40.1	2.5507
40.2	2.5501
40.3	2.5501
40.4	2.5526

Time (s)	Voltage (V)
40.5	2.5507
40.6	2.5513
40.7	2.5507
40.8	2.5501
40.9	2.5513
41	2.5526
41.1	2.5507
41.2	2.5501
41.3	2.5501
41.4	2.5501
41.5	2.5495
41.6	2.5501
41.7	2.5495
41.8	2.5507
41.9	2.5495
42	2.552
42.1	2.5495
42.2	2.5532
42.3	2.5513
42.4	2.5526
42.5	2.5495
42.6	2.5526
42.7	2.5495
42.8	2.552
42.9	2.5495
43	2.5483
43.1	2.5507
43.2	2.5507
43.3	2.5483
43.4	2.5501
43.5	2.5495
43.6	2.5489
43.7	2.5501
43.8	2.5483
43.9	2.5489
44	2.5471
44.1	2.5501
44.2	2.5507
44.3	2.5483
44.4	2.5483
44.5	2.5495
44.6	2.5489
44.7	2.5489
44.8	2.5532
44.9	2.5501
45	2.5477
45.1	2.5477
45.2	2.5495
45.3	2.5483
45.4	2.5489
45.5	2.5489
45.6	2.5495
45.7	2.5489
45.8	2.5477
45.9	2.5483
46	2.5495
46.1	2.5495
46.2	2.5483
46.3	2.5489
46.4	2.5477
46.5	2.5495
46.6	2.5507
46.7	2.5471
46.8	2.544
46.9	2.5483
47	2.5465
47.1	2.5501
47.2	2.5471
47.3	2.5477
47.4	2.5513
47.5	2.5465
47.6	2.5471
47.7	2.5465
47.8	2.5495
47.9	2.5495
48	2.5483
48.1	2.5483
48.2	2.5465
48.3	2.5471
48.4	2.5471
48.5	2.5489

Time (s)	Voltage (V)
48.6	2.5452
48.7	2.5477
48.8	2.5477
48.9	2.5489
49	2.5465
49.1	2.5459
49.2	2.5471
49.3	2.5483
49.4	2.5477
49.5	2.5465
49.6	2.5507
49.7	2.5459
49.8	2.5483
49.9	2.5471
50	2.5483
50.1	2.5471
50.2	2.5483
50.3	2.5495
50.4	2.5477
50.5	2.5477
50.6	2.5489
50.7	2.5471
50.8	2.5459
50.9	2.5465
51	2.5495
51.1	2.5459
51.2	2.5459
51.3	2.5501
51.4	2.5477
51.5	2.5452
51.6	2.5452
51.7	2.5446
51.8	2.5471
51.9	2.5477
52	2.5452
52.1	2.5465
52.2	2.5452
52.3	2.5446
52.4	2.5459
52.5	2.5471
52.6	2.5452
52.7	2.5465
52.8	2.5483
52.9	2.5452
53	2.5459
53.1	2.5459
53.2	2.5477
53.3	2.5459
53.4	2.5471
53.5	2.5477
53.6	2.5477
53.7	2.5459
53.8	2.5471
53.9	2.5465
54	2.5428
54.1	2.5446
54.2	2.5483
54.3	2.5471
54.4	2.5452
54.5	2.5446
54.6	2.5446
54.7	2.5459
54.8	2.5477
54.9	2.5459
55	2.5465
55.1	2.5459
55.2	2.5446
55.3	2.5452
55.4	2.5465
55.5	2.5446
55.6	2.5446
55.7	2.5446
55.8	2.5471
55.9	2.5459
56	2.5471
56.1	2.544
56.2	2.544
56.3	2.5446
56.4	2.5465
56.5	2.5434
56.6	2.5452
56.7	2.544
56.8	2.5446
56.9	2.5471
57	2.5465
57.1	2.5452
57.2	2.5446
57.3	2.544
57.4	2.5428
57.5	2.5434
57.6	2.544
57.7	2.544
57.8	2.5446
57.9	2.5452
58	2.5422
58.1	2.5452
58.2	2.5434
58.3	2.544
58.4	2.5434
58.5	2.544
58.6	2.544
58.7	2.5434
58.8	2.5452
58.9	2.5434
59	2.5428
59.1	2.5428
59.2	2.5446
59.3	2.544
59.4	2.5434
59.5	2.544
59.6	2.5434
59.7	2.5434
59.8	2.5422
59.9	2.5428
60	2.5428